Popular Astronomy.

Vol. V. No. 9. JANUARY, 1898. Whole No. 49.

THE ORBIT OF Σ 2107.

S. W. BURNHAM.

FOR POPULAR ASTRONOMY.

The close pair, Σ 2107, was discovered by Struve, and first measured by him in 1828. It required but a few years to show a sensible change in the position-angle, and for the last twenty years it has been certain that these stars form a binary system. It has been well measured by most of the leading observers since the conclusion of Struve's observations, and we now have as full and accurate material as could be furnished in a pair of this class so far as the angular motion is concerned for an investigation of the relative movement. The total arc described by the companion star from Struve to the present time in about 160°.

Two orbits have been computed for this pair, using the measures down to 1879 and 1883 respectively:

1879	Casey	98 5 years	A. N. 2438
1883	Berberich	186.21 years	A. N. 2623

On the accompanying diagram I have laid down to scale the following measures of this pair by well known double star observers:

1829.01	3n	Struve	1878.57	4n	Dembowski
1836.54	6n	Struve	1879.59	3n	Hall
1841.04	4n	O. Struve	1881.53	2n	Hall
1846.41	6n	Madler	1882.51	6n	Schiaparelli
1851.24	8n	O. Struve	1883.60	7n	Schiaparelli
1854.18	5n	O. Struve	1884.78	5n	Schiaparelli
1863.01	14n	*O* Σ and *Δ*	1886.56	4n	Schiaparelli
1865.08	12n	Dembowski	1887.51	8n	Schiaparelli
1867.11	8n	Dembowski	1888.60	2n	Hall
1868.88	8n	Dembowski	1892.60	4n	Comstock
1870.84	10n	Dembowski	1895 29	3n	Barnard
1872.91	9n	Dembowski	1896 57	5n	Comstock and Leavenworth
1874.25	3n	O. Struve			
1875.03	8n	Dembowski	1897.35	3n	Aitken
1877.29	14n	*O* Σ and *Δ*			

The greater part of these measures were made by the most experienced observers, and the positions are determined from a sufficient number of nights to give as good a result as the respective observers could obtain.

It is evident from an inspection of the diagram that at the time of the investigations referred to, the data furnished by the

measures could not give the faintest clue to the apparent ellipse, or any element of the real orbit, and it is not surprising that the period of one computer is nearly double that of the other. The arc at that time was less than 90°; and, as I have repeatedly pointed out before, there is no possible case where the ellipse can be even guessed at from micrometer measures confined to so limited an angular path, and even now the additional measures leave the problem as indeterminate as it ever was. It is extremely rare that an angular motion of 180° is sufficient, and in many cases 270° or more is required for any investigation of an orbit from which any accurate result is expected. In this case it is not certain that motion through three quadrants will answer the purpose, but in any event we shall have to wait until the companion has passed well into the first quadrant before it will be worth while making any further investigation of the orbit.

YERKES OBSERVATORY, Dec. 4.

THE ORBIT OF Σ 1216.

S. W. BURNHAM.

FOR POPULAR ASTRONOMY.

The distance of this pair has never much exceeded 0″.5 since its discovery by Struve in 1825, and there are but few measures in the first half of the century. In fact, no one else but Madler attempted to measure it, and the single observations by him credited to this pair in 1842-44 (*Dorpat Observations*, Vols. X, XI) certainly belong to some other pair, and probably to Σ 1205 which corresponds in angle and distance to Madler's positions. In 1845 he measured Σ 1216 on four nights, giving the only place we have between the measures of Struve in 1825, and O. Struve in 1851.

On the diagram I have given all the complete measures of this pair down to the present time. There are some other measures of the position-angle by different observers, but as they are as discordant as the others, they add nothing of value to the other material. It is evident that all that can be said of the motion is that the angle has apparently increased about 70° since the measures of Struve, without any change in the distance. The measures are very inconsistent, and give no certain indication of the real character of the relative change.

From the measures down to 1891, Gore has computed the or-

bit (*A. N.* 3283), and found a period of 174.73 years. It is hardly necessary to say that there is nothing in the present data to warrant any statement concerning the elements of the orbit. It will probably turn out to be a binary system, but the observations down to this time do not establish even this relation with any certainty.

YERKES OBSERVATORY, Dec. 4.

ON THE COMPUTATION OF OCCULTATIONS OF STARS BY THE MOON.

G. W. HOUGH.

FOR POPULAR ASTRONOMY.

A half century ago the observation of occultations of stars by the Moon furnished the best method for ascertaining longitude. At the present day, however, this method has been almost wholly superseded by means of telegraphic signals. By the use of the telegraph lines and the ocean cables, the difference of longitude between widely separated stations has been ascertained with a high degree of precision and we can now reverse the problem and from an observed occultation determine the place of the Moon with very great accuracy.

The marked increase in the size of telescopes during the past twenty-five years, enables the astronomer to observe stars of much smaller magnitude than formerly was possible.

The American Ephemeris, now publishes annually, a list of 180 stars which may be occulted by the Moon. The catalogue, with the exception of thirty or forty, is made up of the brighter stars, or those visible to the naked eye. In addition to this list a few standard clock stars should be included.

A telescope having a 12-inch object-glass should afford ample power for the observation of the disappearance or reappearance of an 8th magnitude star, of Argelander's scale, at the dark limb of the Moon.

With the 18½-inch refractor of the Dearborn Observatory, I have observed occultations of the 9th mag. at the dark limb, with just as much ease as a brighter star.

A catalogue of stars occulted by the Moon containing all the stars brighter and including 8th mag. would probably furnish

* Since the above was written, Battermann has published in *Astr. Nach.*, No. 3457-8, a long list of occultations observed, including stars of 9.4 mag.

at least one star, which would be occulted at any given place, on every night. By means of occultations the Moon can be observed for position, further from the meridian than in any other way.

The immersion or emersion at the dark limb of the Moon is a phenomenon, which may be observed with the greatest precision if one uses a chronograph for recording the time.

The personal equation, for recording an instantaneous phenomenon, by pressing a key, is about 0.2 sec. and does not vary very much for different persons. In other words, the personal equation, for this class of observations would be almost wholly eliminated.

The immersion of a bright star at the bright limb of the Moon, may be recorded with some degree of precision but the emersion at the bright limb will always be recorded too late by an unknown quantity.

The prediction of an occultation by Besssel's method requires more time in computation than the working astronomer can well afford. I computed some auxiliary tables to be used with this method, but even with this help the process was too long for every day use.

Some months since I began the computation of parallax tables, in order to facilitate the computation of occultations.

Loomis' Practical Astronomy contains tables for the latitude of Cambridge Observatory. The computations are carried to 0.01 sec. for R. A. and 0″.1 for declination, but the tables are not sufficiently expanded to be of use in the saving of labor.

In *Astr. Nach.* No. 3433, Battermann has published more expanded tables, for a mean parallax of 57′, for the latitude of Berlin, and has included formulæ for the correction to be applied for any latitude between 45° and 60°. An approximate parallax can be taken out very quickly for Berlin, but if one needs a more precise value, the double interpolation and reduction for change in parallax consumes considerable time.

The Berlin tables contain about 3,000 arguments and represents a good deal of labor in their preparation.

I computed tables, on a slightly different plan from either of the above. The tables were intended to be correct within 0.01 sec. in R. A. and 0″.3 in declination. They were computed for a mean parallax of 57′. The parallax in R. A. was computed for every minute of hour-angle and for a declination of 0 degrees, comprising 440 arguments. A second table, occupying one page gave the correction on 100 sec. for every tenth of a degree declination. A third table, contained on a single page, gave the correction for

different values of p. A fourth, double entry table, arguments hour-angle and decl. gave a small outstanding correction amounting in the maximum to 0.19 sec.

With these tables the parallax in R. A. could be taken out to 0.01 sec. by the successive additions of small quantities.

The parallax in decl. was tabulated for every 10 min. of hour-angle and 5 degree of decl. together with the variation for dh, $d\delta$ and the correction for seconds differences.

A second table gave the correction for different values of p, and a short double entry table for outstandi..g errors, amounting in the maximum to 2″.5. The parallax in declination could be taken out by successive additions within 0″.5 arc.

Tables made after this plan are objectionable on account of the large number of small quantities necessary to be added or subtracted, and hence increases the chance for numerical error in computation.

I have spent considerable time in the endeavor to find an expeditious method for computing parallax. I think the following is the shortest one hitherto used. The general formulæ may be found in Chauvenet or Loomis.

Notation: $\pi\alpha$ = parallax in R. A.
$\pi\delta$ = " " Decl.
φ' = Geocentric Latitude.
p = horizontal parallax of the place.
δ = declination of the Moon.
h = hour angle.

$$\sin \pi\alpha = \frac{\sin p. \cos \varphi'}{15 \cos \delta} . \sin (h + \pi\alpha)$$

$$\sin \pi\delta = \sin p. \sin \varphi'. \frac{\sin (b - \delta + \pi\delta)}{\sin b}$$

For the parallax of planets, etc., the arc is substituted for the sine without error. As the parallax of the Moon never exceeds 61′ of arc, it occurred to me that the approximate formulæ might be used to advantage, provided a table of corrections was computed, having h and p as the arguments.

It was found on trial, however, using extreme values of p, $\pi\alpha$ and $\pi\delta$ that the error incident to the use of the approximate formulæ could never amount to 0.01 sec. on $\pi\alpha$ or 0″.05 on $\pi\delta$, which is all that is required.

In securing so close an agreement with the rigorous formulæ, the value of log p must be corrected for the difference between the arc and sine. For a mean value of p the correction is 20 units on six figure logarithms.

In some logarithmic tables the correction for sine and tangent is given on each page of the logarithms of numbers.

The rigorous formulæ then becomes

$$\pi\alpha = \frac{p \cos \varphi'}{15 \cos \delta} \sin (h + \pi\alpha)$$

$$\pi\delta = p \sin \varphi' \cdot \frac{\sin (b - \delta + \pi\delta)}{\sin b}.$$

These formulæ are easily computed even without the help of auxiliary tables.

For the prediction of an occultation extreme accuracy in the parallaxes is of little advantage, since the problem can only be solved by successive approximations.

It has been found that 4 place logarithms would usually give $\pi\alpha$ within 0.03 sec. and $\pi\delta$ within 0″.5, which is all that is needed.

To adapt the formulæ for rapid computation $\log \frac{p \cos \varphi'}{15}$ should be tabulated for every 10″ of p (48 arguments), log sec δ, tabulated for every 10′ from 0° to 29°, the first 5 deg. to single degrees only, a total of 150 arguments.

The two tables will occupy one page. The log sin h should be tabulated for every minute of hour-angle up to 440. It is easily prepared by copying the log-sin of every 15′.

In the formula $\pi\delta$, log $p \sin \varphi'$ should be tabulated for every 10″ of p and b should be computed for every minute of hour-angle, and tabulated together with log cosec b.

If only 4 place logarithms are used b may be taken out to the nearest 0′.5.

The tabulation of the value of b, to the nearest second of arc, using 6 place log.'s involves considerable labor.

The formula is

$$\cot b = \frac{\cos \left(h + \frac{1}{2}\pi\alpha\right) \cot \varphi'}{\cos \frac{1}{2}\pi\alpha}$$

The $\cos \frac{1}{2}\pi\alpha$, varies with the hour-angle, but its maximum value only amounts to 11 units on 6-place logarithms.

The best method is to compute b for every tenth argument and interpolate with second differences. If the first and second differences are computed for each set of 20 arguments, the successive additions may be made by any one who knows how to add, since there is no chance whatever for error, if the differences are written down.

For my tables b was computed with 6-place logarithms and tabulated to the nearest second, but this degree of precision is unnecessary, if required for predictions only.

$\frac{\sin h \cos \varphi'}{15}$ was also taken out with 6-place logarithms.

The preparation of tables on this plan is a very simple matter, and will require only a fraction of the time necessary for the computation of tables such as I have mentioned based on a mean value of the parallax.

When tables have been prepared in the manner I have indicated, a parallax in R. A. or Decl. is obtained simply by the addition of three logarithms of 4 figures each.

The tables for $p\alpha$, $p\delta$ and δ are placed on a single sheet of cardboard.

The log $\pi\alpha$ may be written down directly, and for $\pi\delta$ only one quantity need be taken for the general tables, viz:

$$\log \sin (b - \delta + \pi\delta).$$

The facility of computation depends on the scheme of using $(h + \pi\alpha)$ and $\left(h + \frac{1}{2}\pi\alpha\right)$ as arguments instead of h.

The following specimen tables show the plan as outlined above:

TABLE 1.

Arg. $(h + \pi\alpha)$				Arg. $\left(h + \frac{1}{2}\pi\alpha\right)$				
h	$\sin(h+\pi\alpha)$	Diff. $0^m.1$	$\Delta\pi\alpha$ 10^s	b			Diff. $0^m.1$	Co sec. b.
m			sec	°	′	″	″	
200	9.8843	1.6	+ 0.078	54	20	58	51.0	0.0901
1	.8858	1.6			29	28	51.3	.0893
2	.8874	1.6			38	01	51.7	.0886
3	.8890	1.5			46	38	52.1	.0879
4	.8905	1.5			55	19	52.4	.0871
5	.8920	1.5	+ 0.076	55	04	03	52.9	.0863

TABLE 2.

Arg. p.	$\pi\alpha$ $p \cos \frac{\varphi'}{15}$	$\pi\delta$ $p \sin \varphi'$
″		
56 00	2.2222	3.3507
10	.2235	.3520
20	.2248	.3533
30	.2261	.3546
40	.2274	.3559
50	.2287	.3572
57 00	.2299	.3584

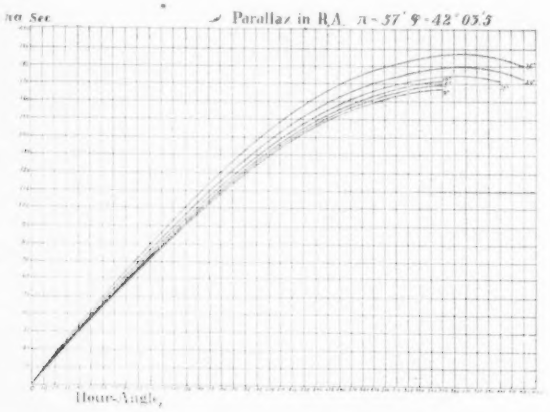
	Diff.
″	
1	1
2	3
3	4
4	5
5	7
6	8
7	9
8	11
9	12

TABLE 3.

Arg. Decl.		Sec. δ.
°	′	
23	00	0.0360
	10	.0365
	20	.0371
	30	.0376
	40	.0382
	50	.0387
24	00	.0393

EXPLANATION OF THE TABLES.

1st col. = hour angle; 2nd sin h, to be taken out with the argument $(h + \pi\alpha)$, 3d, diff. for 0^m.1, 4th, correction to be applied for an error of 10 sec. on the assumed value of $\pi\alpha$, 5th, b to be taken out with the argument $\left(h + \frac{1}{2}\pi\alpha\right)$, 6th diff. for 0^m.1, 7th, log cosec. b.



In order to get the greatest benefit from tables constructed as above, it is desirable to plot curves which will show at a glance the approximate value of $\pi\alpha$ and $\pi\delta$ for a mean parallax of 57′.

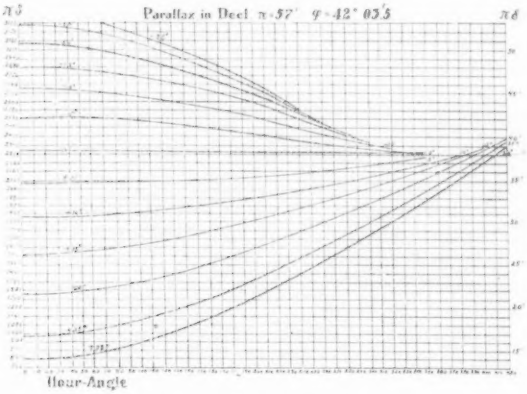
We will now compute the parallax, using the partial tables already given.

We will in this case suppose the parallaxes are wholly unknown. In order to get an approximate value of $\pi\alpha$ we may write down the arguments from Table 2 and 3, and mentally add the first two figures of the logarithms including log sin h, the number so obtained may be used as the approximate value of $\pi\alpha$.

Let $h = 201^m.47$		$p = 56'\ 27''.8$	$\delta = +23°\ 38'$
Arg. pT_2	2.2258	The approximate sum of first	
" σT_2	0.0381	two figures is $2.44 = 138'' = 2^m.3$	
Arg $203.77\ T_1$	9.8902	Hence $(h + \pi\alpha) = 203^m.77$	
Log $\pi\alpha = 2.1541$		(Diff 4".6) cor	+ 0.08
cor + 1			
$\pi\alpha = 142.60$			
cor + 0.03			
$\frac{1}{2}\pi\alpha = 71^s.3 = 1^m.22$		$(h + \frac{1}{2}\pi\alpha) = 202^m.69$	Arg. for b.
Arg. $p\ T_2$	3.3543	$b =$	54° 44′
log cosec b	0.0881	$\delta = +$	23 38
sin Σ	9.7181	$b - \delta =$	31 06
Log $\pi\delta$	3.1605	$\pi\delta$	24
$\pi\delta = 1447''.1 = 24'\ 07''.1$		$(b - \delta + \pi\delta) = 31$	$30 = \Sigma$

The approximate value of $\pi\delta$ was got in the same manner as $\pi\alpha$.

By using 6-figure logarithms the values of $\pi\alpha$ and $\pi\delta$ for the above example were found to be 142.60 sec. and 1446″.7 respectively.



The advantage of this method over any form of table computed for a mean value of the parallax is, that one can get an accurate value in less time, than one can interpolate an approximate parallax, which finally must be multiplied by $\frac{p}{57}$, or reduced by the use of a second table.

We will now proceed to the computation of occultations for Oct. 30, 1897.

It was found that two stars would be occulted when the Moon was above the horizon.

The apparent places are

Arg. *W.* 15265	$\alpha = 19^h\ 14^m\ 29^s.25$	$\delta = -28°\ 23'\ 40''.7$
X_3 Sagittarii	19 19 19 .17	−24 09 49 .1

We will give the computation for Arg. *W.* 15265 for 11^h and 12^h Gr. M. T.

From the *American Ephemeris* take out R. A. and Decl. of the Moon, horizontal parallax, semi-diameter and determine the local hour-angle.

COMPUTATION OF PARALLAX.

	h m	h
Gr. M. T. =	11 00.00	12 Gr. M. T.
Long.	5 50.70	
Local M. T.	5 09.30	
Cor.	+0 85	
Sid.T. Noon	14 37.21	
Sid. T.	19 47.30	20 47.52
$\mathbb{C}.\alpha$	19 13.17	19 15.68
h	+34.19	+1 31.84
π	59′ 15.4	59′ 08.3
Cor. Lat.	−5.3	−5.3
p =	59′ 10″.1	59′ 08″.3
S =	16 10 .0	16 10 .1
$\pi\alpha$ =	26ˢ = 0ᵐ.43	72ˢ = 1ᵐ.2
$h + \pi\alpha$ =	34ᵐ.62	93ᵐ.04
log sin $(h + \pi\alpha)$	7.8731	8 2924
log $p\alpha$	3.5502	3.5500
Sec δ	0.0381	0 0372
$\pi\alpha$ =	28ˢ.94	75ˢ.78
Cor.	+.03	+0 03

Computation for $\pi\delta$.	11ʰ Gr. M. T.	12ʰ Gr. M. T.
$h + \frac{1}{2}\pi\alpha$ =	34ᵐ.43	92ᵐ.47
b =	42° 11′	44° 15′
δ −	23 37	−23 22
$\pi\delta$	54	52
Σ =	66° 42′	68° 29′
cosec b =	0.1728	0.1562
$P\delta$ =	3.3747	3.3744
sin Σ =	9.9631	9.9686
log $\pi\delta$ =	3.5106	3.4992
$\pi\delta$ =	3240″.4	3156.5
$\pi\delta$ =	54′ 00″.4	Cor. +.3
		52′ 36″.8

Augmentation		$\mathbb{C}$. semi diam.
Arg. S =	7 6724	7.6724
$\pi\delta$ =	3.5106	3 4992
cot $(b - \delta)$ =	9.6527	9 6147
	0.8357	0.7863
	6″.85	6″.11
cor.	−0 .12	−0 .11
Aug =	6″.73	6″ 00

The assumed values of $\pi\alpha$ and $\pi\delta$ were read from the curves. For augmentation: Arg. S. and the small corrections were taken from the tables.

Moon 11ʰ Gr. M. T.		Moon 12ʰ Gr. M. T.	
α = 19ʰ 13ᵐ 09.99	δ = −23° 37′ 15″.7	19 15 40.81	−23° 29′ 47″.7
$\pi\alpha$ − 28 97	$\pi\delta$ − 54 00 .4	$\pi\alpha$ 1 15.81	$\pi\delta$ −52 36 .8
19 12 41.02	−24° 31′ 16″.1	19 14 25.00	−24 22 24 .5
* 19 14 29 25	−24 23 40 .7	19 14 29.21	−24 23 40 .7
* $\Delta\alpha$ + 1ᵐ 48ˢ.23	$\Delta\delta$ + 7′ 35″.4	* $\Delta\alpha$ + 4ˢ.25	* $\Delta\delta$ − 1′ 16″.2
log 108.23 = 2.0343			
log 15 = 1.1761			
log cos δ = 9.9592			
$\Delta\alpha_1$ = + 1477″.8	$\Delta\delta_1$ = + 455″.4	$\Delta\alpha_2$ = + 58″.0	$\Delta\delta_2$ = − 76″.2
S_1 = 16′ 10″.60			
Aug. + 6 .73			
S_0 = 16′ 17″.33			

With a radius S_0, draw a circle to represent the Moon, and draw the two diameters. The bottom of the diagram will be north, or 0 degrees, position angle; the right side following, or 90 deg. The diagram will represent the Moon as seen in an inverting telescope.

Lay off $\Delta\alpha_1$, $\Delta\alpha_2$, $\Delta\delta_1$ and $\Delta\delta_2$, which gives the position of the star with reference to the Moon, at 11ʰ and 12ʰ respectively.

Draw the line to represent the apparent track of the star, and measure with a dividers and scale the distance between the two positions of the star, which divided by 60 will be the apparent motion in one minute. Measure the distance of the star from the limb at immersion and emersion, and divide by the motion in one minute, which will give the approximate time of contact.

If the point of contact of the star with the limb of the Moon, lies between the positions chosen, the time usually will be correct within 0.5 min. or less. The position angles may be measured within one degree with a protractor. I have used a scale, about 3.5 inches in length for the radius of the Moon, and divided only to 20″ of arc.

Since the apparent motion of the star is usually 24″ to 30″, in one minute of time, a measurement of the diagram within 5″, would involve an error of only one quarter of a minute in the time of contact.

By regarding the star in motion, instead of the Moon, we get a very simple diagram and the positions of the star with reference to the Moon are the same as would be seen in the telescope.

In the diagram
$CA = \Delta\alpha_1 = +1447''.8$
$CB = \Delta\alpha_2 = +\ 58\ .0$
$AD = \Delta\delta_1 = +\ 455\ .4$
$BE = \Delta\delta_2 = -\ 76\ .2$
$ED = 1518''$ motion in 1 hour
$\frac{DF}{dm} = \Delta t$ $dm = 25''.3$ $DF = +567''$
$\Delta t_1 = +22^m.41$
$T_1 = 11^h\ 22^m.41$ Gr. M. T.
Position angle $NCF = 75°$

The computation might have stopped at this point, but in case we wish a correct solution for the coördinates used, it may be very quickly accomplished by making $CG^2 + GF^2 = CF^2 = S_0^2$.

We interpolate a new value for S_0, for the approximate time of contact already found, and determine the hourly motion in R. A. and decl.

$\Delta\alpha_1 - \Delta\alpha_2 = 1419''.8$ motion in one minute $23''.66$
$\Delta\delta_1 - \Delta\delta_2 = 531\ .6$ " " $8\ .86$

Thence for $\Delta t = +21^m.41$ motion in R. A. $= 530.1$
" decl. $= 198.5$

and we get

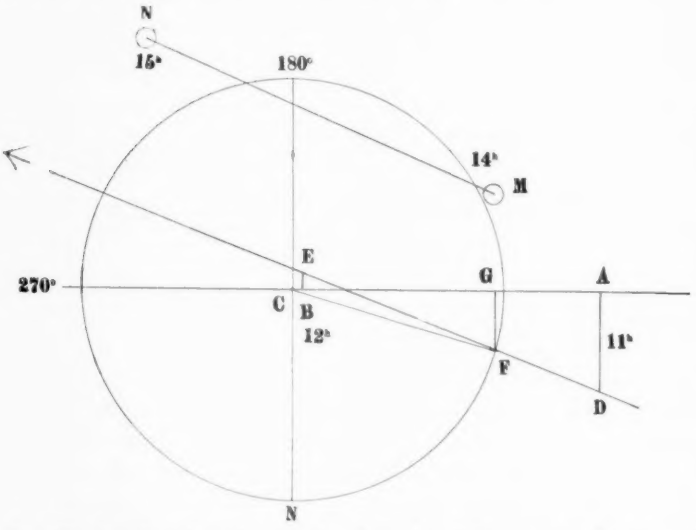
$CG = \alpha' = 947''.7$ $2 \log 5\ 9534$ $\alpha^2 = 8982$
$GF = \delta' = 256\ .9$ " 4.8194 $\delta^2 = 660$
sum 9642
$\frac{1}{2}\log = 2\ 9221$
$S = 982.0$
$S_0 = 976.9$
$dS = +5''.1$

The value of dS shows the coördinates are too great. As the variation in S in this case will be approximately the same as dm we increase the time 0.25 min. and compute new values for CG and GF we find

$\alpha'' = 941''.8$
$\delta'' = 254\ .7$
$S'' = 975\ .8$
$S_0 = 976\ .9$
$dS = -1''.1$

We find 1 min. $= 24''.4\ ds.$
cor. for $5''.1 = +\ 0^m.21$
$T_1 = 11^h\ 22^m.61$

The above computation will generally be omitted and instead a 3d pair of coördinates computed for the approximate time given by the measurement of the diagram.



I will simply give the results for the 3d computation as the process is precisely the same as has already been used for the 1st pair.

$\pi\alpha = -47''.19 \qquad \pi\delta = -53'\ 42''.2 \qquad \alpha' = +949''.5 \qquad \delta' = +268''.4$
$S = 986.7$
$S_0 = 976.9$

$ds = +9''.8 \qquad \Delta t = +0^m.37$
$T = 11^h\ 22^m.61 + 0^m.37 = 11^h\ 22^m.98.$

The measurement of the diagram, in connection with a third coördinate, makes the definite determination of the time of contact a very short process.

The following are all the results:

Measurement of diagram	$T = 11^h\ 22^m.41$ Gr. M. T.
Computed	22 .61 "
3rd coördinate	22 .98 "
Immersion observed	$11^h\ 22^m\ 52^s.1$

The coördinates for X_3 Sagittarii were:

$$\Delta\alpha_1 = +956''.5,\quad \Delta\alpha_2 = -741''.3,\quad \Delta\delta_1 = -506''.8,\quad \Delta\delta_2 = -1229''.1$$

$T_1 = 14^h\ 06^m.0$ by measurement.

$14^h\ 06^m\ 12^s.2$ Im. observed.

In order not to complicate the diagram I have omitted drawing the coördinates for X_3 Sagittarii. The points M and N are the relative positions of the star at 14^h and 15^h Gr. M. T.

Some time may be saved by computing the coördinates for even hours of Gr. M. T. as it is only necessary to copy the geocentric places as given in the *American Ephemeris*.

For an immersion an error of a minute in the predicted time is a matter of no consequence, but for an emersion I like to know the time within a few seconds and hence use a third set of coördinates computed for the approximate time given by measurement.

In any case the third place is useful as a check on any gross error in computation, for when laid down on the diagram, the apparent path of the star should not deviate sensibly from a straight line.

Tables for the reduction of the horizontal parallax for latitude, may be found in Chauvenet or Loomis.

A table is also given by Loomis for the correction on the Moon's declination, depending on the difference of R. A. between the Moon and star. The correction will seldom amount to more than 1″ of arc and may be neglected for the first pair of coördinates.

The formulæ for the augmentation of the Moon's semi-diameter may be written as follows:

$$\text{Aug} = [4.6856]\, S.\pi\delta \cot (b - \delta) - \frac{1}{2} S \sin^2 \pi\delta.$$

The quantity $\frac{1}{2} S \sin^2 \pi\delta$, is small, its maximum value being $-0''.12$. It may be quickly tabulated for a mean value of S, with $\pi\delta$ for the argument. The $\log \frac{S}{\sin 1''}$ may be tabulated for every 10″ of S, from 14′ to 17′.

When parallaxes are computed on the plan given, it is only necessary to take out cot $(b - \delta)$ from the general tables, and one can get an accurate value of the augmentation, much quicker

than an approximate value from a double entry table, having for arguments the hour-angle and declination.

I had previously computed a double entry table for every 10 min. of hour-angle and 5 deg. of declination.

To ascertain quickly what stars may be occulted, within a given interval I take the M. T. of passage of the Moon over the meridian and determine the approximate hour-angles corresponding to two or more even hours of Gr. M. T.

The parallaxes are then read roughly, from the curves, viz, within 5 sec. on R. A. and 1′ Decl. If the star is in the *American Ephemeris* list a simple inspection will show the approximate time of apparent conjunction. If D. M. or Arg. W. catalogues are used, the places of the Moon are reduced to the epoch of the catalogue.

One can ascertain in a few minutes what stars are likely to be occulted. In some cases, however, if the star passes near the north or south limbs, a more exact determination may be necessary.

For an immersion the R. A. of the star is greater than that of the Moon; for an emersion, less. When the star is occulted near the middle of the disk the difference in R. A. is about 1.5 min.

By constructing a diagram and using the approximate results found as above, the times of contact may be ascertained within 5 minutes without further computation.

For the observation of an emersion at the dark limb of the Moon, if a power of 150 or 200 is used, the field will be comparatively small, and it is desirable to have the telescope pointed so that the emersion will take place near the center of the field.

From the diagram ascertain the distance in minutes of arc of the point at which the emersion occurs, with reference to the center of the disk, and point the telescope by means of the finder, using the bright limb and equator of the disk as reference points. The finder of the 18½ in. has been provided with a micrometer for both R. A. and decl. and by its use the telescope can be pointed very accurately. This precaution is essential, if one expects to see the star at the exact instant of its re-appearance; for if the emersion takes place near the edge of the field the observation will always be recorded too late.

Dearborn Observatory, Northwestern University,
Nov. 29, 1897.

ON THE CAUSE OF THE SCINTILLATION OF THE FIXED STARS.

T. J. J. SEE.

Recent studies of the air waves visible in telescopes have led me to connect these aerial agitations with the scintillation of the fixed stars. These undulatory phenomena have not been considered by previous investigators, and it seems probable that they constitute the true cause of stellar scintillation, which has heretofore been somewhat obscure. The air waves having been sufficiently described in previous papers, we may here consider the effect of such waves upon the images of telescopes of various apertures. In the case of the naked eye, the aperture from which the light is gathered is about 2 millimetres in diameter, and hence any intercepting wave which might turn the light of the star to one side by this amount would cause the star to twinkle suddenly; or if it did not wholly disappear, the wave would at least disperse the light into a spectrum and the eye would recognize a change in brightness and a rapid succession of spectral colors. The action of a wave is essentially similar to that of a lens, for it must always distort the luminous wave-front; but it would seldom happen that the eye would be in the focus of the wave (if indeed there be any exact focus), and hence while there would be incessant fluctuation in brightness as the waves pass before the eye, there would also be a rapid succession of colors. If we consider one wave, which we may imagine of the form of a double convex lens, the eye being supposed between the wave and its principal focus, it is clear that as the wave intercepted the light of the star the eye would first encounter a spectrum running from the red to the blue; as the centre of the wave passed, the colors would change gradually again in the reverse order. This is essentially the phenomenon observed in ordinary naked-eye scintillation. In practice it would rarely happen that a simple perfect wave such as we have supposed would pass before the eye, but it is easy to see that however complicated and antagonistic the actual waves might be, the appearance at certain irregular intervals would be essentially that here described. If in the small area covering the pupil the rays from different waves or different parts of the same wave should interfere (as must occasionally happen) there would be total momentary extinction of the star. When the interference did not amount to extinction there would be a sudden diminution and then an increase in brightness, with a play of successive

colors. If the waves happened to be conspicuous, the scintillation would be correspondingly marked. We have seen that length of the waves vary from 1 to 20 centimetres (occasionally the length even surpasses 40 centimetres), and hence with a finite velocity of atmospheric movement there would be a certain time elapsing between the succession of colors from the different portions of the wave, the interval depending on the velocity of the current and the size of the wave. If the simple waves are superposed into compound waves, this interval might be lengthened or shortened to any corresponding degree. In case the intervals became too short, the eye would be unable to perceive anything but a blurring impression. At other instants more widely separated the flashes would be clear and distinct, as is frequently observed, and especially when the waves are large and conspicuous.

I have recently compared the scintillation in telescopes of apertures 2.54; 5.18; 10.16; 15.24; 61.0 centimetres, with the following general results:

1. When the waves are conspicuous and violent, the scintillation is marked both to the naked eye and in the smaller telescopes.

2. When the waves are small there is no proper scintillation in the larger telescopes, though parts of the image undergo considerable motion and dispersion of color; yet scintillation continues in the telescopes of small aperture, and is always noticeable with the naked eye.

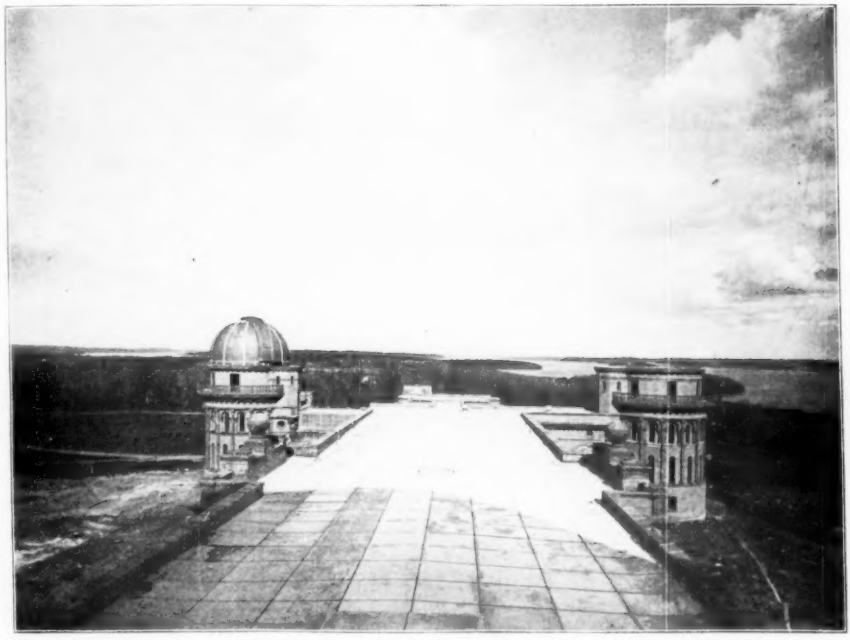
3. When the length of the wave surpasses the aperture of the telescope there is always some scintillation; while if the waves are shorter than the diameter of the objective, only partial scintillation or none at all can be perceived.

4. We have never seen any distinct scintillation in the 61.0 centimetre refractor, although on a few occasions when the waves were large and conspicuous the image of a star displayed considerable motion, and more than usual fluctuation of color.

5. The intensity of the scintillation is a function of the altitude of the star above the horizon. This may be explained by the fact that low down the numerous successive waves superposed in the line of vision frequently act as combined waves and thus increase the visible effects upon the star's brightness, position and color.

6. To connect the waves directly with the scintillation in such a way as to leave no doubt of the cause of the phenomena, I have on several occasions counted by careful watching the number of flashes in ten seconds, the time signals being taken by Mr. Cogshall; in this way we have found that the number of flashes is

PLATE XXVIII.



E. E. Barnard, Photographer.

Yerkes Observatory.

View from the rotunda of the great dome of the Yerkes Observatory, looking southeast, showing the south eastern portion of Lake Geneva. The small body of water to the left of the small dome is Lake Como. The two lakes are separate, the strip of water seen among the trees to the right of this small dome is Williams Bay, a portion of Lake Geneva. The railway station of Williams Bay is hidden by the trees just to the left of the small dome. The power house of the Observatory is partly hidden by this dome. Since the picture was made, the tower to the right has received its dome, the small dome to the left contains Professor Hale's 12-in. from the Kenwood Observatory Station.

sensibly the same for all altitudes higher than 30°. Having thus fixed the rate of scintillation, we then examined without delay the number of violent wave agitations noticed to pass the field of the great telescope; and it was found that the number of large waves passing the objective was sensibly the same as the number of flashes observed with the naked eye. This number on the average was about 22 for ten seconds. Our counts on α Scorpii, α Boötis, α Lyrae, and α Ursae Majoris at 17^h sidereal time, showed that the number of flashes in different parts of the sky was sensibly the same, so that the direction of the currents relative to the observer seem to have very little to do with the twinkling. It was remarked that sometimes as many as four flashes would occur within one second, while at other times only one could be perceived; only such flashes and waves being taken account of as were recognized with certainty.

7. It seems incorrect to state that the refraction proper varies from moment to moment. It varies gradually from hour to hour owing to continuous fluctuation of the barometric pressure, temperature and humidity; but the small momentary changes in the apparent position of a star are like those which affect the shape of the image and disperse the colors, and are to be attributed solely to the momentary combinations of air waves which intercept the light of the star.

8. When the flow of the currents is exceedingly gentle and smooth, and the atmospheric waves are practically absent, scintillation ought almost to cease; and we have actually confirmed this inference by observation, though even in the best localities these intervals of calm are rare and of short duration. Humboldt mentions the stillness of the stars and the almost total absence of conspicuous scintillation in the plains of Peru (Cosmos, Vol. III p. 103, Bohn's Translation). The good seeing at the Harvard Station near Arequipa may be regarded as another confirmation of this result in our own time, from a somewhat different point of view.

In the Philosophical Magazine for July 1893,* Lord Raleigh has very fully considered the theories of scintillation held by previous writers, and given at considerable length the analysis for the effects of refraction on the path of the light through the atmosphere. He intimates that the true cause of the scintillation is obscure, in this language: "One of the principal outstanding difficulties in the theory of scintillation is to see how the transi-

* Reprinted in Astronomy and Astrophysics, Nov. and Dec. 1893.

tion from one index to another in an atmospheric irregularity can be sufficiently sudden. The fact that the various parts of a not too small object glass are diversely affected seems to prove that the transition in question does not occupy many centimetres. Now whether the irregularity be due to temperature or moisture, we should expect that a transition, however abrupt at first, would after a few minutes or hours be eased off to a greater degree than would accord with the above estimate. Perhaps the abruptness of transition is, as it were, continually renewed by the coming into contact of fresh portions of light and dense air as the ascending and descending streams proceed in their courses. The speculations and experiments of Jevons on the cirrus form of clouds (Phil. Mag. XIV p. 22, 1857) may find some application here. A preliminary question requiring attention is as to the origin of the irregularities which cause scintillation."

Lord Raleigh concludes that the present state of Meteorology does not explain the origin or character of the irregularities to which scintillation is due. It is clear from the discussion above, and from the descriptions of the air waves published by Mr. Douglas * and the writer, that the atmospheric irregularities which cause scintillation are at last recognized; it is not yet quite clear how these waves are maintained though the suggestions advanced in the accompanying paper seem plausible.

Lord Raleigh attaches considerable importance to the dispersive action of the atmosphere upon the red and blue rays, which are thus separated and made to pursue different paths in the vertical plane. I conceive this dispersion to have a bearing on the scintillation only in this way: That when the rays of the star are thus separated, the red being above the blue, it is perhaps easier for a chance combination of the waves to still further separate the extremes of the spectrum, or to extinguish one part while the other part remains, and thus produce a change in color or a variation in brightness.

On the wave-theory it is easy to account for the sudden transition from one phase to another, and for all the general phenomena considered by previous observers. The spectroscopic observations of Respighi quoted by Raleigh also find complete explanation, as do also the relation of the phenomena to altitude and to aperture of telescope. It is needless to add that this theory accounts perfectly for the absence of scintillation in the case of planets with large discs; for in this case the waves are generally

* After finishing this paper I find that Mr. Douglass has suggested a connection between scintillation and cross-currents (Popular Astronomy, June, 1897).

shorter than the angular diameter of the planet, and consequently cannot affect the light of the whole; so that the eye perceives no change comparable to that observed among the stars, though there must be scintillation of points on the surface. It is well known that when the seeing is bad the planetary image of Mars, for example, is frequently displaced by almost half its diameter, and sensible distortion of form is very common. This bodily displacement as well as the shifting of points on the surface, so frequently noticed by the observers of planetary detail, is traceable to the action of the air waves, which distort the luminous wave-front entering the telescope.

Thus while the wave-theory certainly assigns the true cause of the scintillation of the fixed stars, considerable observation is still needed for delineating the exact forms of the waves under all conditions and for investigating their effects upon the steadiness of stellar images.—*Astr. Nachr. Bd. 144.*

LOWELL OBSERVATORY, Flagstaff, Arizona, 1897 Aug. 24.

THE FIXED STARS. VIII.

W. H. S. MONCK.

FOR POPULAR ASTRONOMY.

The spectra of the vast majority of the stars belong to the types which have been described as Sirian, Capellan or Arcturian. A smaller number, however possess peculiar spectra and of this latter class a large proportion are variable stars.

Probably almost all the stars including the Sun vary more or less in their light. The Sun can hardly give as much when half covered with sun-spots as when entirely free from them. But the change must be considerable in order to be perceived. The easiest mode of observing variableness is by noticing that one star is alternately brighter and fainter than another; as for instance in the case of Aldebaran and Betelguese which are nearly of the same color and not very distant. No such comparison can be made in the case of the Sun, and it is difficult to make it in that of a very bright star. Sirius might probably vary to the extent of quarter of a magnitude without anyone noticing the fact. I am inclined to think that Arcturus actually varies but the fact cannot be said to be ascertained. Variability is of different kinds. Eclipse-stars have been already noticed. So far as is known at present these stars, together with the short period binaries

discovered by the spectroscope, appear to be all or almost all of the Sirian type. On the tidal theory, now largely accepted, such binaries are probably at an early stage of evolution and their periods may be expected to become gradually longer. But it would seem that eclipse-stars are the only variable stars of the Sirian type, while I doubt if there is a single Capellan star whose variableness has been established. Some of the Arcturians appear to be variable but the Arcturian spectrum glides by insensible degrees into the type of Antares or Betelguese designated *M* in the *Draper Catalogue* where the proportion of variables is very large. Banded spectra as opposed to linear spectra are indicative of variableness, while bright lines in the spectrum of a star seem to be even more closely connected with it.

New stars should undoubtedly be classed as variable stars though perhaps they do not always belong to the same class of variable stars. If a star varies between the 5th and 10th magnitudes it will be visible to the naked eye at its maximum while at its minimum it would probably not be bright enough to be found in any star-map or catalogue. *Mira Ceti* would probably be classed as a new star if its maxima were less frequent or if it was only at an unusually high maximum that it became visible to the naked eye. Mr. Gore's New Star in Orion is undoubtedly of this kind. New stars when followed by powerful instruments can always be kept in view. Very probably most of them are not periodic like Mira and Gore's star. The great accession of light which gave them the character of new stars may never occur again. But in this respect they agree for example with the well-known variable star η Argus for which at all events no period can at present be assigned.

An obvious cause of variableness (besides eclipses) is collision. Under the influence of gravity, collisions must sometimes occur, and every collision will produce an increase in the light given by the colliding bodies. It might even create a new star in a pretty strict sense by rendering one or both of two dark bodies luminous. Some years ago I suggested a cause agreeing pretty closely with collision for the new star in Andromeda—the rush of a star through a gaseous nebula. Though gaseous nebula are (so far as we at present know) much less numerous than stars, yet from their great volume it is perhaps more probable that a star should rush through one of them than that two stars should collide. If swarms of meteors exist in space, as they probably do, a good deal of light might be produced by a star rushing into a dense meteor-swarm. Professor Lockyer speaks of the collision of two

meteor-swarms; but unless the component meteors were packed together much more closely than any that we are acquainted with but little light could be given out in such a case. It will be seen however that more than one kind of collision is possible and that the phenomena in the case of different kinds of collisions would be different. In the case of the rush of a star (or of a meteor-swarm) through a gaseous nebula, the rushing body might ultimately be vaporized, as the majority of the meteors which enter our own atmosphere are, and at the final stage we would obtain the spectrum of a gaseous nebula only; while the rush of the star might by heating the gaseous nebula render it visible where it was too faint to be noticed before the star entered it. There are reasons for thinking that the majority of new stars arise from collision in one form or other. Their spectra often exhibit double lines apparently coming from two bodies whose velocities in the line of sight differ considerably. They usually occur in or near nebulæ and at one stage present an almost pure nebular spectrum—sometimes even a nebular disc of measurable dimensions. The spectrum of a collision-star may of course be expected to be in some respects peculiar. It will be double or else it will exhibit the bright nebular lines superposed on the spectrum of the star. Collision will vaporize some of the matter of the colliding bodies and increase the heat of their atmospheres and may in this way produce bright gas-lines where there was originally no nebula. Indeed if the star-atmospheres were deep and dense the the whole force of the collision might be spent on them with little or no effect on the nucleus, the result being evinced partly by the appearance of bright lines and partly by the dying out of dark ones. The entire subject requires careful study. We must in fact distinguish between the effects of (1) Simple collision of two solid bodies; (2) Of a solid body with a meteor-swarm; (3) Of two solid bodies, one or both being surrounded by gaseous atmospheres; (4) Of a solid body with a gaseous nebula; (5) Of a meteor-swarm with a gaseous nebula; (6) Of a solid body surrounded by a gaseous atmosphere with a gaseous nebula; (7) Of two meteor swarms and (8) Of two gaseous nebulæ. And there may be other possible kinds of collision.

But the connection between variableness and peculiar spectra—banded spectra in particular—suggests that in many cases we should look for the cause of variation not in an eclipsing body or in a colliding body but in the star itself. Here our best ground for conjecture is our actual experience. The Sun's light is probably affected by two causes: (1) The number of sun-spots, (2)

The extent of the corona. The Earth's light as viewed from a planet is probably affected by other causes, viz; the relative amount of land, water and cloud turned towards it. The light of Saturn is affected by another cause—the position of the rings. How far are such causes as these applicable to the stars? The phenomena of some variable stars bear a considerable resemblance to those of sun-spots. They are roughly but not accurately periodic. Some of the minima are lower than others as if the number of spots was increased. The spectra especially at the minima resemble that of a sun-spot rather than the ordinary spectrum of the Sun. The diminution of light is much greater and the period much shorter than in the case of the Sun, but perhaps an exaggeration of the phenomenon would also shorten the period. A volcano when dying out may give feeble explosions at long intervals: when active, the explosions may be more frequent as well as more violent. The energy which produces sun-spots is perhaps the same as that which at a more advanced stage of cooling produces volcanoes. That matter is often projected from the Sun and sometimes with great violence seems certain. How far the same thing occurs with stars whose spectra are of a different kind is at present conjectural: but if sun-spots should prove to be connected with these volcanic eruptions, as seems probable, the indications of similar spots afforded by some of the stellar spectra must not be disregarded.

Another cause of variation which has been suggested is rotation. Rotation however could only produce variation in case of some want of symmetry in the star either in the shape or in the degree of illumination. It must turn towards us either a larger surface or a brighter surface at one time than at another. We should be slow to deny the possibility of such want of symmetry among bodies of which we know so little, but the supposition is not favored by the analogy of anything known to us. Most of the heavenly bodies are probably ellipsoidal, but the axis of revolution is so situated as not to present to us the smaller and larger dimensions of the ellipsoid at different times; and if any of them possess rings like Saturn it is not likely that different parts of the ring would be turned towards us at different times. Saturn would not do so if removed to a sufficient distance.

Eclipse-stars, as noticed, are probably at an early stage of evolution and if the Sirian spectrum indicates this stage we may expect to find them usually Sirians. Collision seems as likely to happen to a star with one kind of spectrum as with another save that a star in a state of rarity will occupy more space than a

dense one and therefore will have a greater chance of coming into contact with something else. The effects of collision however will be more marked when a star is comparatively cool as the accession of light will in that event be more startling. Superficial disturbances probably depend largely on the spectrum of the star or rather on the conditions of temperature, density, etc., indicated by that spectrum. As to want of symmetry in a revolving star I have no means of ascertaining in what cases it is most likely to occur if it occurs at all. Collisions are of course most probable where stars are most closely packed together, viz, in the galaxy or in clusters.

It often happens that the components of a double star are of almost equal brightness. In this case different observers regard different components as the brighter and accordingly differ from each other by 180° in the measurement of the position-angle. But sometimes there seems to be a general consensus among observers that one star is the brighter of the pair at one time while at another time there seems to be a like consensus in favor of the companion. In such cases it would seem as if one or both stars were variable. Something similar has been noticed in the case of a comet dividing into two parts. Sometimes one part is brighter and sometimes the other. In such cases there is another possible cause of variableness—mutual action of some kind between the pair.

It is evident that an eruption, whether it is to be called volcanic or not, on the surface of a star if sufficiently violent will project matter into space which will revolve in an ellipse parabola or hyperbola without again falling into the generating star. Many astronomers believe that the Sun actually projects matter in this way at the present day. This was the origin which the late Mr. Proctor assigned to comets, and it would also account for the existence of meteors in space whether they are to be identified with comets or not. Nor is this origin inconsistent with Professor Lockyer's meteoric theory though that theory seems to me less probable than the rival nebular hypothesis. Though stars were originally formed from the condensation of meteor-clouds still under certain circumstances they might again eject some of the generating meteors. But whatever the origin of meteors may be, there is no reason to suppose that they are confined to the solar system and the supposition of meteor-swarms helps to explain more than one phenomenon in the stellar regions.

Besides stars proper, the sky contains no small number of nebulæ. But what are nebulæ? They do not appear to be all

of the same kind. Some objects which were once supposed to be nebulæ are indeed now known to be clusters of stars which were too close together or too distant from us to be separated by the telescopes formerly used. But others present the bright-hue spectrum of a gas though apparently of a gas not composed of terrestrial elements. The Great Nebula in Andromeda indicates a different kind of Nebula from both. The spectrum is continuous like that of a solid but cut off at the red end, and I think it may now be regarded as certain that notwithstanding its non-gaseous spectrum this nebula is not resolvable into stars. The small stars which surround it—and they are very numerous— however seem to have a connection with the nebula, and many astronomers regard it as an example of a stellar system in the very process of evolution from a nebula. Something similar to the nebulous rings from which Laplace supposes that the planets were formed are indeed visible in the photographs of this nebula. But the supposition that we can here see a stellar system in the process of evolution is little more than a conjecture, and if such be the fact the process is taking place on so vast a scale that probably centuries will elapse before stars can be traced in the spaces now occupied by the nebula rings. I am disposed to think that the Great Nebula in Orion differs from its rival in Andromeda rather in its materials than its stage of evolution; for the one is surrounded by Sirian stars of the most brilliant type (*B*) while the stars round the other are red or orange stars of the Arcturian class. Assuming that these stars have been formed from the respective nebulæ and that the process of formation is still in progress, it seems necessary to assume a difference of nebulous material. The irregular shape of the Orion nebula also contrasts with the almost regular curves of that in Andromeda. The difference between nebulæ will perhaps prove to be quite as striking as the differences between stars.

There seems to be an inverse relation between stars and nebulæ which favors the theory of evolution. It is reported that Sir W. Herschel when sweeping along the Galaxy used to tell his sister to prepare to write nebulæ whenever the stars became unusually thin. And the richest region of nebulæ certainly lies outside of the Galaxy. The Constellation Virgo literally swarms with them. If nebulæ are stars in embryo, it can hardly be said that the stars —or rather the star-matter—is crowded into the region of the Milky Way. Materials for the construction of stars exist in great multiplicity outside of that famous circle and as the nebulæ (so far as we can judge at present) appear to be situated at great

distances from us this displacement of them cannot be the effect of perspective. Careful study of the Magellanic clouds where star clusters and nebulæ are blended together in apparent confusion may tend to clear up the relations between them.

One remark on this subject is worth making. On the theory of evolution we would naturally suppose that the brilliant Sirian or rather Orionic stars were first formed from nebulæ and that these gradually cooled down to the Capellan, Arcturian and Antarian types respectively. But it is the Antarian type of star which exhibits the most decided traces of variableness in its light and this variableness again appears to be closely connected with the nebulæ characteristics. These facts suggest a problem which is yet unsolved. I am disposed to think there are two kinds of nebulæ of which the Orion and Andromeda nebulæ may be taken as types; that these give rise to or are connected with two different classes of Stars viz. the Orionic or Sirian and the Antarian or Arcturian, and that the stars of the Capellan type are formed by cooling from one or perhaps from both of these classes of primary stars. The majority of the stars have of course been formed many ages ago. Hence the Sirians are more numerous than the Orionic Stars from which they are derived and the Arcturians more numerous than the Antarians which were perhaps their primitive form.

A small number of Stars have recently been discovered with spectra approximating more closely to that of a nebulæ. They are known as stars of the Wolff-Rayet type and so far appear to have been found only in the Galaxy. It will be interesting to note whether they vary in their light or not. But when we recollect how recently the spectroscope was invented and how recently we have had anything like accurate measures of the relative intensity of the light of different stars it is not surprising that we know so little. It is rather surprising that we know so much. For a single man—though aided by his talented wife—Dr. Huggins has worked wonders, and the results attained at Harvard, Potsdam, Mount Hamilton and other Observatories cannot fail to bear fruit hereafter. We have discovered much in the last quarter of a century. In the next we shall probably discover more

ON NEWTON'S LAW OF GRAVITATION.*

About two years ago† I drew attention to certain difficulties arising out of the attempt to extend Newton's law of gravitation to infinite space. The considerations then adduced, showed the necessity of choosing between two hypotheses; viz: 1. *The sum total of the masses of the universe is infinitely great, in which case Newton's law cannot be regarded as a mathematically exact expression for the attractive forces in operation.* 2. *The Newtonian law is rigorously exact, in which case the infinite spaces of the universe cannot be filled with matter of finite density.* Inasmuch as I am wholly unable to find adequate reasons for the second of these assumptions, I have, in another place, decided in favor of the first. Since reaching this conclusion, it has come to my knowledge, that Carl Neumann‡ had called attention still earlier, to difficulties of a similar kind which may be regarded, in a sense, as special cases of the arguments I brought forward. The concurrence of so prominent a scientist, as also the circumstance that the considerations adduced by myself, are expressible in another form without essential modification of their contents, may perhaps make a return to this subject seem superfluous. But it appears to me the entire question is so fraught with significance for the whole of theoretical astronomy as to merit thoroughgoing and perspicuous treatment. It is moreover, obvious that my former remarks have met with serious misunderstanding and misapprehension. That this is true, is manifest even from the connections in which my article has been cited. For these reasons, it seems to me far from useless to discuss this matter again. This discussion will constitute the subject-matter of the first part of the present dissertation.

The problem under treatment, has some points of resemblance to another well known question. Cheseaux and after him, Olbers propounded the question as to why the average brightness of the celestial vault is so very small, whereas it should be comparable with solar brightness, if the number of luminous bodies in the universe be assumed infinitely large. It seems all the more desirable to treat this problem more fundamentally than was formerly done, since, by so doing, it appears that Olbers' conclusions are far from being entirely free from objection. Olbers explains the

* Paper by Professor H. Seeliger, Munich, Germany, published in the proceedings of the Bavarian Academy, November, '97, and translated by G. W. Myers, University of Illinois.

† Ueber das Newton'sche Gravitations-Gesetz *A. N.* No. 3273.

‡ *Conf.* Carl Neumann. Allgemeine Untersuchungen ueber das Newton'sche Prinzip, etc. Leipzig 1896. p. 1.

seeming paradox, as is well known, by the extinction of light in interstellar spaces. The permissibility of this assumption cannot of course, be contested; its necessity, however, does not by any means, follow from an unbiased study of the question.

I.

To compute the combined attraction which all the masses of the universe exercise upon a given material point, we may advantageously replace the actual masses, by a continuous distribution of matter, filling an arbitrarily large portion of space. This may be done very simply by regarding the individual bodies as spheres whose densities are arranged in concentric shells. The attraction of such spheres upon outside points is not altered by expanding the matter disposed thus in concentric layers of arbitrary dimensions, to any desired extent, so long as the attracted point remains outside of all the shells. We may also deal similarly with the individual parts of these layers and obtain thus a continuous distribution of cosmic matter and it is obvious that such distribution may be secured in an indefinite number of ways. Any one of such mass distributions would fill an extended portion of space, and would exert upon any particular point the same attraction as would the original body from which it was formed. If this space be of finite extent, the density must also be everywhere finite. As is easily seen, we may also perform this substitution of a continuous distribution for the actual distribution of matter in such wise that the density at any point will be a function of its coördinates, continuous, except in certain surfaces, lines, and points, i. e. continuous within certain regions. Integrations therefore, throughout such regions of this mass-distribution would present neither difficulty nor doubt.

Speaking rigorously, the heavenly bodies are of course not spheres, composed of matter thus concentrically arranged. They are however, very nearly so, so nearly so, in fact, that the above mentioned substitution will express the actual forces of attraction to within a very small percentage of the whole and this is entirely sufficient, since, in the sequel, only the question as to whether the involved expressions for the attracting forces become infinite or indefinite requires an answer. Moreover, an extended treatment would show that the introduction of continuous mass-distribution is rigorously justifiable.

The attraction then, which any arbitrary point A, actually experiences will be the same as that which a mass-filled space, of density everywhere equal to δ, exerts upon it. Let a limited por-

tion of space, P, then, contain within its superficial boundary a hollow, within which A is situated and let the exterior limit of the body be so chosen as to exclude all other bodies of the universe. Within P, which, let us suppose, is determined by the radii R_0 and R_1, δ may be assumed everywhere finite, continuous within certain regions and nowhere equal to zero. Furthermore, within finite portions of P, δ may even be equal to zero, without invalidating any of the conclusions, although it is hardly necessary to take cognizance of this fact.

In the vicinity of A, at the distance $AO = a$, from A, locate the origin of a system of rectangular coördinates. Let ρ and r be the distances of an element of mass dm, from the points A and O respectively; γ, the angle $dmOA$; φ the angle between the plane $dmOA$ and a fixed plane passing through a. If then, the potential of the forces of attraction between dm and A be given as $f(\rho)$, the entire potential of the attraction exerted upon A becomes

$$V = \int_0^{2\pi} d\varphi \int_0^{\pi} \sin\gamma d\gamma \int_{R_0}^{R_1} \delta f(\rho) \cdot r^2 dr.$$

From this we obtain easily the magnitudes

$$X = \frac{dV}{da} \text{ and } Z = \frac{d^2V}{da^2}, \text{ for } a = 0.$$

If, for convenience, we introduce the Laplace-Legendrian functions:

$$P^1 = P^1(\cos\gamma) = \cos\gamma; \quad P^2 = \frac{3}{2}\cos^2\gamma - \frac{1}{2}$$

we have,

$$\left.\begin{aligned} X &= -\int_0^{2\pi} d\varphi \int_0^{\pi} P^1 \sin\gamma d\gamma \int_{R_0}^{R_1} \delta f'(\rho)\, r^2 dr \\ Z &= \tfrac{2}{3}\int_0^{2\pi} d\varphi \int_0^{\pi} \sin\gamma d\gamma \int_{R_0}^{R_1} \delta\, r^2 dr \left\{ \frac{1}{r} \cdot f'(r) + \frac{1}{2} f''(r) + P^2 \right. \\ &\qquad \left. \left[f''(r) - \frac{1}{r} f'(r) \right] \right\} \end{aligned}\right\} \text{I.}$$

X is the acceleration of the point O in the direction a. The quantity Z, I have elsewhere called the *strain*, for $Z\Delta a$ is the acceleration, with which the two points situated at the infinitely small distance Δa, from each other, strive to separate. The special case in which $f(r) = \frac{1}{r^1 + \alpha}$ will be considered immediately. For this case we have:

$$\left.\begin{aligned} V_1 &= \int_0^{2\pi} d\varphi \int_0^{\pi} \sin\gamma d\gamma \int_{R_0}^{R_1} \delta . r^{1-\alpha} dr \\ X_1 &= (1+\alpha) \int_0^{2\pi} d\varphi \int_0^{\pi} P^1 . \sin\gamma d\gamma \int_{R_0}^{R_1} \delta . \frac{dr}{r^\alpha} \\ Z_1 &= \frac{1+\alpha}{3} . \int_0^{2\pi} d\varphi \int_0^{\pi} [\alpha + 2\,(3+\alpha) .\ P^2] \sin\gamma d\gamma \int_{R_0}^{R_1} \delta . \frac{dr}{r^{1+\alpha}} \end{aligned}\right\} \quad 1)$$

For Newton's Law $\alpha = 0$, and consequently, for it;

$$\left.\begin{aligned} V_2 &= \int_0^{2\pi} d\varphi \int_0^{\pi} \sin\gamma d\gamma \int_{R_0}^{R_1} \delta .\ r\ dr \\ X_2 &= \int_0^{2\pi} d\varphi \int_0^{\pi} P^1 . \sin\gamma d\gamma \int_{R_0}^{R_1} \delta .\ dr \\ Z_2 &= 2 \int_0^{2\pi} d\varphi \int_0^{\pi} P^2 . \sin\gamma d\gamma \int_{R_0}^{R_1} \delta .\ \frac{dr}{r} \end{aligned}\right\} \quad (2)$$

These expressions will be considered first. R_0 is a finite magnitude, R_1, on the contrary, becomes greater and greater, the more of the universe we seek to comprehend. It increases therefore indefinitely and finally becomes infinity. But the integrals taken with respect to r in (2) become meaningless, since they represent wholly indefinite infinities. This occurs when, within infinitely great distances, δ has finite values different from 0. In this case, V_2, X_2, and Z_2 are also in general, meaningless. The forces affecting the point A, and also the constitution of the matter within it, which is at the same time determined by the *strain*, are given by means of wholly indefinite, and hence, meaningless expressions. They are therefore, for us just as little known, or knowable, as the limits themselves of the infinitely extended universe are conceivable to us. The question is however, somewhat different, if we make R_1 depend upon γ and φ in a prescribed way. The only means of attaining this, is that, in which one approximates to the representation of an infinite space. We select a portion of space with definite, though variable, limits and cause it to increase to infinity, by causing its limit to expand incessantly according to definite laws. We may, for example, select a sphere and allow the radius to increase indefinitely, or, we may choose an ellipsoid and cause it to grow into ever larger and larger confocal ellipsoids. What surfaces we take as fundamental and according to what laws we cause them to expand are wholly matters of discretion. This is of course, merely another way of saying that R_1 is an entirely arbitrary function of γ and φ, which, with increasing r, according to any law whatsoever, assumes

infinitely great values. If then δ be represented by a known function, R_1 may always be so chosen that X_2 and Z_2 may preserve a definite, though wholly arbitrary significance, and may, or may not, assume definite values. The former may be easily effected, for example, if the integrals

$$\int_{R_0}^{R_1} \delta_1 \, dr \qquad \text{and} \qquad \int_{R_0}^{R_1} \delta_1 \, \frac{dr}{r}$$

are developable in spherical harmonics, and if the harmonics of the first order in the first integral, and those of the second order in the second integral, have finite coefficients. As a very simple example, we may conceive δ to be constant and R_1 to represent the radius of an ever increasing sphere. Then X_2 and Z_2 are continually equal to zero, as is known also from the theory of attraction of homogeneous spheres. The number of such assumptions as this is of course, infinitely small compared with all possible and as is to be specially emphasized, equally *justifiable* assumptions.

We may then, say that if δ is given as a function of the position of the point, where the density equals δ_1, we may in general, so choose R_1 as a function of γ and φ, that V_2, X_2 and Z_2 assume all arbitrary magnitudes, and conversely, with every prescribed value of R_1, δ may be so chosen that the quantities mentioned, again assume arbitrary values and hence, for example, become infinite.

To illustrate, we have just assumed that δ equals a constant. If in this case, R_1 denotes the radius of a sphere about A as center, then as above mentioned $X_2 = Z_2 = 0$ and these quantities remain finite under all circumstances, if R_0 define any surface whatever, since this surface is at all points within the range of finite magnitudes. If however, we take the center of the infinitely large sphere at the distance c from A, the point is drawn toward the center with the force $\frac{4}{3}\pi\delta \, . \, c$, while the stress in the same direction always equals a finite constant multiplied by δ. If now, we make c arbitrarily great and ultimately, infinitely great, the acceleration also becomes greater than any number whatsoever, and its direction is completely undetermined, since the center of the sphere may be situated in any desired direction from A. This is the example which Carl Neumann adduces. He correctly designates the demonstrated consequence of Newton's law as absurd and concludes from it that the law of attraction leads to contradictions in the case of an homogeneous distribution of matter.

ON THE NATURE OF THE SMALL AIR WAVES VISIBLE IN CURRENTS OBSERVED THROUGH TELESCOPES.

T. J. J. SEE.

Having considered in some previous papers (A. N. 3438, 3449) the effects of air currents or elements of currents (called waves) upon telescopic definition and upon photography, it seems desirable to add a few remarks on the probable nature of these waves.

If we examine a stream of clear water flowing over gravel (as in the case of a mountain brook) we shall see that the surface of the fluid is convoluted into many small elements, so that the boundary of the fluid is a surface of the greatest complexity. When the depth of the water is constant and the bed of the stream fixed, the folds in the surface of the moving water are stationary; the elements of this convoluted surface are functions of the velocity of the stream, and of the shape of the bottom, and if the currents are moderately simple the theory of fluid motion enables us to investigate this surface mathematically. As the depth of the fluid varies from point to point, and the different elements of the surface are variously inclined to the level, it is clear that the light from any luminous source falling upon that surface will be refracted in the most irregular manner; thus the light that reaches any point of the bottom of the stream will come from various directions, and on being reflected from the bottom will strike the multiple surface at all angles and the most confused refractions will result. The rays that reach the eye of the observer from any given point of the surface will thus proceed from various points in the bed of the stream separated by considerable spaces. But as all the images thus emerging from any point are projected in that direction, the result is the superposition in one point, of images which ought in fact to be widely separated; and on the other hand images which should be adjacent are often widely separated by the action of the distorting surface.

Thus the superposition of images from neighboring points destroys the definition. But though the images are blurred, yet if we keep the eye in a fixed position (the source of the light being also fixed), the appearance of the bed of the stream is unchanged so long as the flow of the fluid and consequently the external surface is fixed.

In the case of the air currents the surface as well as the medium is moving, and hence the effect upon the definition is similar to that which would result from moving the eye rapidly over the

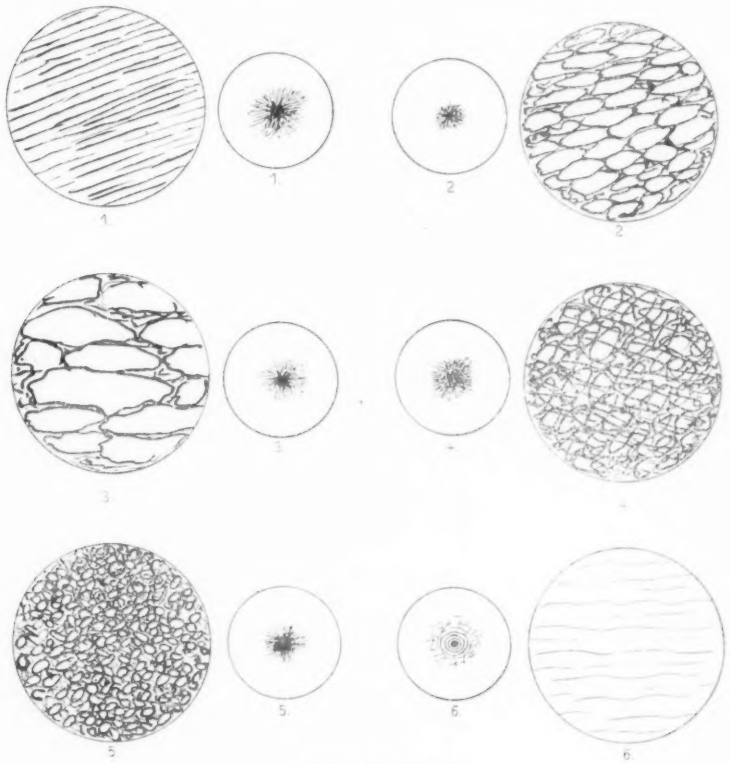
stream of water — i. e. the images are blurred and the appearance changes from instant to instant. As the air waves which follow one another in the field of view at any time are more or less similar, there is a certain approach to constancy in the sum total of the refractions produced by all the waves in the field of the telescope, and thus the light forms a changing composite image. The appearance of the air waves seen in a telescope pointed on a bright star is very similar to, though less brilliant than, the dancing reflections of the sun's image from water flowing over gravel.

In the case of the air however, we have to deal with a highly compressible fluid, and hence we are not so much concerned with irregularities, due to flow of the atmosphere over the earth's surface (though when the ground is rough this must have some effect on the state of the lower masses of air), as we are with the small differences of temperature and pressure existing throughout the atmosphere and constantly maintained by the general circulation, and considerably increased by friction in particular regions where the currents are antagonistic.

When the air is in motion it appears that the effect of the thermal convection and of internal friction is to produce a great number of very small streams or elements of currents; these waves which follow one another are to be understood as stream-lines in the air which vary in density or temperature. As the light in different portions of a wave is thereby diffused or condensed, the appearance is one of varying brightness. The section through the axis of the stream-line and perpendicular to the line of vision is doubtless similar to the one we see; and hence it is clear that the principal refraction of the light is in the plane of the current, though the exact result in any given case depends entirely upon the form of the waves.

If several of these waves in the lower regions of the air, not far from the telescope, chanced to be superposed in such a way that their refractive effects were of the same algebraic sign, the resultant effect upon the light entering the telescope would of course be very much increased, while if the combinations were antagonistic the effects of the waves might be almost annulled. It is in this way doubtless that the various changing effects of the waves are produced. Thus, so far as I have been able to determine from observation, it seems that the waves are elements of the stream-lines, and are visible because of very slight variations in the density due to slight inequalities of temperature, or vice versa, depending on the thermal condition of the atmosphere and on the effects of the internal friction of the fluid. The presence of water

vapor in the air complicates the problem; for the slightest difference in humidity with the least change in density or temperature of adjacent portions must cause circulation and a re-adjustment of the thermal equilibrium of those portions; and I suspect that in these inevitable inequalities of pressure or temperature will be



WAVES AND IMAGES.

found the explanation of the incessant agitation of the waves as the large currents move rapidly along. The importance of these phenomena as atmospheric movements affecting all astronomical work, aside from their high meteorological interest, is such as to justify a prolonged and critical study under the best conditions. Until this is done some of the effects may remain obscure; yet it seems fairly certain that the general character of the disturbances are as here indicated, and I have ventured to submit these considerations in the hope that they may be of interest to other observers.

EXPLANATION OF THE PLATE.

Fig. 1. Represents a frequent form of the waves when the wind is very high; definition generally very bad.

Fig. 2. Represents moderate sized waves; definition generally very fair.

Fig. 3. Represents very large waves; definition generally bad.

Fig. 4. Represents cross currents; definition depends on the character of the waves, but is frequently bad.

Fig. 5. Represents very fine waves moving in all directions, characteristic of very hot, dry weather; definition generally bad.

Fig. 6. Represents very fine seeing, only slight traces of gently moving waves.

In theoretically perfect seeing there should be no trace of any atmospheric movement whatever.—*Astr. Nachr. Bd. 144.*]

LOWELL OBSERVATORY, Flagstaff, Arizona, 1897, Aug. 23.

AN HISTORIC "GREGORIAN."

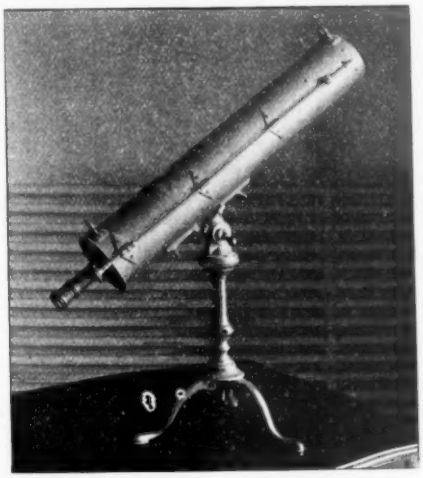
ALDEN W. QUIMBY.

FOR POPULAR ASTRONOMY.

While *en route* to the delectable feast of astronomy and astrophysics connected with the dedication of "Yerkes Observatory," the writer spent an enjoyable day at Greenville, Pa., with the Rev. John Peate, D. D., who had recently completed the figuring of a huge glass speculum, sixty-one inches in diameter, for the American University at Washington; and, failing to make close railway connection at Erie, Pa , improved the time by visiting the spot where, a century ago, that brilliant Pennsylvania soldier of the Revolution, Major-General Anthony Wayne, fatally attacked by gout, fought his final battle. A block-house, said to be a *fac simile* of that in which the General breathed his last, has been erected to his memory; and close by is the tomb in which his remains reposed for nearly thirteen years, until their removal by the General's devoted son, Colonel Isaac Wayne; when the vicinity of Presque Isle, washed by the blue waters of Lake Erie, was exchanged for a secluded vale in Delaware county.

The sacred relics found their final resting place in the churchyard of "Old St. David's at Radnor," immortalized in one of Longfellow's poems; and in 1809 the Society of the Cincinnati placed over them a simple marble monument, bearing inscriptions of grateful appreciation of Wayne's services to his country. Scarcely five miles west of the quaint little church, in Chester county, is

the birthplace of the hero of Stony Point; and two miles farther in the same direction brings one to the notable ground where Wayne's brigade suffered a night attack by the British troops under General Gray—an engagement which has long been entitled, but probably unjustly, the "Paoli Massacre." The historic natal mansion is owned and occupied at present by a great-grandson of "Mad Anthony," Captain William Wayne.



General Anthony Wayne's Favorite Telescope.

But that which especially interests the reader with astronomical tastes is the "favorite telescope of General Wayne," which was presented by his son to the "Chester County Academy of Natural Science," in 1831. It has found its way into the possession of Dr. George Morris Philips, Principal of the West Chester State Normal School; and may be seen in the reception room of that well-known institution. The writer is indebted to Dr. Philips's courtesy for the privilege of photographing so valuable a curio.

The telescope is a "Gregorian," twenty-four inches in length, and four inches in diameter. Both the tube and the stand—which is an alt-azimuth pillar-and-claw, fifteen inches in height—are of brass, of exceedingly neat workmanship, the connection between the two being adjustable to permit accurate balancing at various altitudes.

The principal speculum is of metal, three and five-eighths inches

in diameter, and three-eighths of an inch thick, with a central aperture of three-quarters of an inch. The right side of the tube carries a rod with a thread at its upper end, to which is attached through a slot in the tube the mounting for the little concave mirror employed to reflect to the eye-end the rays focussed by the major speculum. The latter can scarcely be considered as enclosed in a "cell," being merely pressed against some little cleats (which prevent it from falling forward in the tube), by springs fastened to the detachable foot of the tube into which the eye-piece is screwed.

There is therefore no provision for changes in "centering," as in the case of a Newtonian; and the focussing is accomplished by slightly shifting the position of the little speculum, by slowly turning the rod in either direction. A "sight" with a very small hole is attached to the eye-end, while another with a greater aperture surmounts the farther end. The cunningly wrought and really beautiful little instrument is a strong temptation to one who has a passion for optical experiments; but, alas! the little mirror has long since hopelessly vanished from its holder.

But no ardent devotee of so precious a souvenir will be altogether baffled in his effort to test the performance of the speculum. The writer cut the Gordian knot by removing it from the tube, and holding it as steadily as possible in his left hand, while with the right he used the eye-piece in imaging a house at some distance. Although much in need of repolishing, the well-figured surface nevertheless gathered sufficient light to present a very pretty terrestial field; and on a previous occasion, when sun spots were larger and more numerous, it was quite a satisfaction to scan a conspicuous group.

The eye-piece consists simply of a plano-convex lens of long focus, and is provided with a light shade-glass of reddish tint for solar observations. Singularly enough no trace of the maker's name appears upon the instrument—perhaps the fine art exhibited in modern advertising was then in its infancy—but one might guess that the telescope was the work of the celebrated Short or his immediate successors.

It would be decidedly interesting to know what use the famous soldier made of this "favorite" acquisition; but unfortunately there is no record of the service rendered by the little "Gregorian." Like the leaden clouds which interfere with carefully laid plans to observe transits and eclipses, a dense veil obscures the theme of our inquiries. Was the prized reflector merely an ornament of the quiet Chester county home used in viewing the charming

country stretching to the south; or did it accompany the general upon his eventful expeditions and render valuable assistance under the standard of Mars?

Since, however, its distinguished owner was a surveyor in his early manhood, we may safely assume that Venus and Mars, Jupiter and Saturn, in turn peered through the little "sights," and yielded to a trained eye such of their treasures as are compassable by an instrument of its capacity; and that sun spots, mountain ridges and craters on the lunar terminator, and some of the wonders of the galaxy were not unknown to the sturdy patriot who sacrificed so much for his country's liberty.

II. NEW CHARTS FOR INSERTING THE MILKY WAY.

A. PANNEKOEK.

For Popular Astronomy.

Among the existing star charts few are adapted for Milky Way studies. Most of them are on far too small a scale and leave no space for drawing the minutest differences of brightness. Without getting too great dimensions we can use a much larger scale because we need only those parts of the sky, that contain the Milky Way. It is especially necessary that the charts contain all the stars visible to the naked eye; with only the 5th magnitude there are great blank spaces where we have no stars to delineate the streamers and spots, and the greater number of the existing maps, especially those which contain the whole sky in one sheet, do not go farther than the 5th magnitude. It is also a matter of great importance that on the maps we have a name to each star: in order to comprehend the meaning of the picture better, we often need verbal descriptions and it is readily conceived that it is not sufficient to use only the names of the brighter stars. And none of the charts I am acquainted with possess this needful quality.

Those, who are engaged in studying the Milky Way will all have experienced this want. At present it has been remedied by the efforts of Mr. C. Easton, already known among the astronomers by his excellent drawings of the Milky Way.

In Volume 53 of the Monthly Notices, Mr. A. Marth has published an extensive catalogue of galactic longitudes and latitudes of stars in the neighborhood of the Milky Way. These offer an excellent opportunity for drawing a star chart in cylindrical pro-

jection by representing the axis of the Milky Way by a straight line through the middle, the galactic parallells by lines parallel to it and the galactic latitude circles by perpendiculars on it. Such charts I had constructed for my private use, directly after the publication of the catalogue. Mr. Easton afterwards lithographed them and they can now be had by any one studying this subject at very slight expense. I will now proceed to describe these charts and the method of using them.

The northern Milky Way region is contained in two charts, each extending 90° in galactic longitude and 50° in galactic latitude (25° on each side of the axis). The first extends from 0° (the intersection with the equator in Aquila) to 90° (the point nearest to the north pole in Cassiopeia), and the other from 90° to 180° longitude (intersection with the equator in Monoceros). The degrees of longitude are everywhere $1° = 5$ min; the degrees of latitude grow smaller with increasing latitude in the ratio of cos. latitude. This is done so that equal parts of the sky in different latitudes may be represented by equal parts of the chart.

In order to prevent confusion only the black points of different size, representing the stars, are drawn on the charts; but the means are given to add, when desired, the lines of equal longitude and latitude which are straight lines in this projection and the names of the stars. The four edges are divided into degrees by short strokes, so that it is easy to draw the straight lines through the chart. On both sides of the chart a margin is added, measuring the fourth part of the breadth of the chart itself; this margin contains the names exactly on the spot where the stars would be placed if the scale of longitudes was the same, and the scale of latitude were reduced to half; the name of each star on the chart is very easy to find on the margin. As each observer uses more than one chart, I should advise filling up one of the charts with the names and the latitude circles and parallels, and to use this chart always as an example for reference.

For the names of the stars I have used firstly, the Greek letters of Bayer and the numbers of Flamsteed. But these are not sufficient. For stars not contained in Flamsteed's catalogue I have made use of the numbers in Baily's British Association Catalogue, which are usually designated by the prefix *B A C* but which in this case, in order to gain space, are placed in parentheses. Some stars of the 6th magnitude remain, that do not occur in the *B A C*. For these I have used the number in the catalogue of Weis (Atlas coelestis novus) with *H* prefixed. The magnitudes of the stars are taken by Marth from the General Catalogue of Pickering.

It should be observed however that the magnitude of the black circles is not always exactly concordant with the visual magnitude, because they are drawn by eye estimate. A few small stars remain that have no names at all. As this might give confusion and uncertainty on filling up the charts with names I have added a list of these anonymous stars, indicated by their galactic longitude and latitued.

°	°	°	°	°	°
9.5	− 18.1*	92.1	+ 1.0	141.7	− 7.7
34.7	+ 10.1	104.0	+ 15.2†	144.2	− 1.9
37.0	+ 0.7	104.8	+ 4.6	145.2	− 14.9
42.9	+ 9.3	106.0	+ 8.9	156.2	− 1.3‖
53.1	+ 0.2	108.3	+ 8.9	156.7	+ 24.3
55.6	+ 20.2	111.7	− 8.1	166.0	− 4.3
61.2	+ 0.2	114.8	− 3.8‡	169.6	− 17.8§
62.2	+ 6.7	118.3	− 0.5	174.0	− 8.8
62.2	+ 8.3	124.8	+ 14.3	176.0	− 8.3
91.3	− 0.3	126.3	+ 21.5	176.6	− 18.6¶
		133.0	− 19.5		

* Between δ and 62 Aquilae. † smaller of two stars. ‡ between (1035) and (1059) ‖ at the right side of χ Orionis. § at the left side of 22 Orionis, ¶ in contact with ι Orionis.

Some errors are found on the charts, for which reason I have appended the following list of corrections

I. Wrong Names of the Stars.

(In the first column the approximate longitude is given, while + or − indicates the sign of the latitude).

°				°				
9 −	Aquila	7	should be η	77 +	Cassiop.	e	should be	1
19 +	Herculis	40	" 100	93 +	Cepheus	(608)	"	(605)
24 +	"	103	" 108	122 −	Perseus	$H26$	"	$H86$
27 +	Lyra	7616	" $H26$	123 +	Camelop.	$H57$	should be	two
30 −	Vulpecula	7640	" $H40$				names 7 (for left, brighter star)	
33 −	"	7650	" $H50$				and $H55$ (for right, fainter star).	
41 +	Cygnus	(6847)	" (6817)	141 −	Taurus	57	should be	51
44 +	"	$H23$	" $H123$	142 −	"	92	"	72
58 +	"	(7405)	" (7105)	147 −	"	ν	"	h
59 +	"	(6853)	" (6852)	148 −	"	155	"	105
63 −	Lacerta	(7618)	" $H18$	149 −	"	g	"	C
63 −	"	p	" (7705)	163 −	Orion	$H16$	"	$H18$
64 −	"	i	" $H6$	163 −	"	$H112$	"	$H102$
66 −	Cygnus	(7476)	" (7676)	164 −	"	(1857)	"	(1851)
72 −	Lacerta	($H30$)	" $H30$	167 −	"	32	"	52
72 +	Cepheus	(9658)	" (7658)	168 −	"	$H63$	"	$H53$
74 +	"	(1766)	" (7766)	172 −	Monoc.	$H1$	"	$H7$
76 +	"	(7943)	" (7973)	154 −	Orion	H	"	omitted

II. Names, that can be Misunderstood by their Resembling other Names.

°				°				
11 −	Aquila	σ	(resembles 5)	106 −	Androm.	C	(resembles	k)
30 −	Vulpecula	$H23$	(" $H28$)	112 −	Perseus	Wiess 34	("	54)
31 +	Cygnus	9	(" ρ)	114 −	"	k	("	10)
51 −	Pegasus	ι	(" i)	114 +	Camelop.	(1751)		
64 −	Lacerta	7628	(" $H23$)	139 +	Auriga	$H23$		
97 −	Androm.	(425)		154 +	Gemini	28		
105 +	Camelop.	(1510)		159 +	"	σ	("	6 or 5)

III. Stars that are Omitted, while their Names are on the Margin.

(The first columns give their galactic longitude and latitude)

°	°				
14.3	+ 2.6	Aquila ζ	3d	magn.	(as γ Aquila)
28.3	+ 14.6	Lyra *H*26	6th	"	(as the smallest on the chart).
44.6	+ 12.0	Cygnus (6731)	5th	"	(as the small star near δ Cygni).
44.9	+ 21.3	Draco (6428)	6th	"	
75.0	− 15.6	Androm. 13	5½	"	
100.3	− 22.4	Androm.(465)	6th	"	
178.9	− 12.5	Canis Minor η	5th	"	(as 1 and 11 Can. min).

IV. False Stars, to be Omitted.

°	°	
1.8	+ 7.9	Ophiuchi.
90.8	− 14.7	Andromeda.
126.5	− 13.0	Perseus.

V. Stars whose Names are Omitted.

°	°		°	°	
16.2	− 4.5	Aquila is ψ	91.2	+ 5.8	Cassiop. is (261)
62.0	− 7.2	Lacerta " (7681)	126.5	− 14.2	Perseus " 40
62.8	− 9.8	" " (7770)	162.9	− 22.9	Orion " 5

VI. Remarks on Boundary Lines.

140° Boundary line around *H*132 and (2261) should be omitted. Both stars belong to Auriga.

°		
170	− 17°.5	The constellation with star β is not Lepus, but Eridanus.
89.8	− 15 .8	*H*38 belongs to Andromeda.
56	+ 24	Name *O*, after the word Draco, should be placed somewhat lower.

The charts may be had free of expense by applying for them to the editor of this journal.

ASTRONOMICAL PHENOMENA DURING 1898.

H. C. WILSON.

Eclipses.

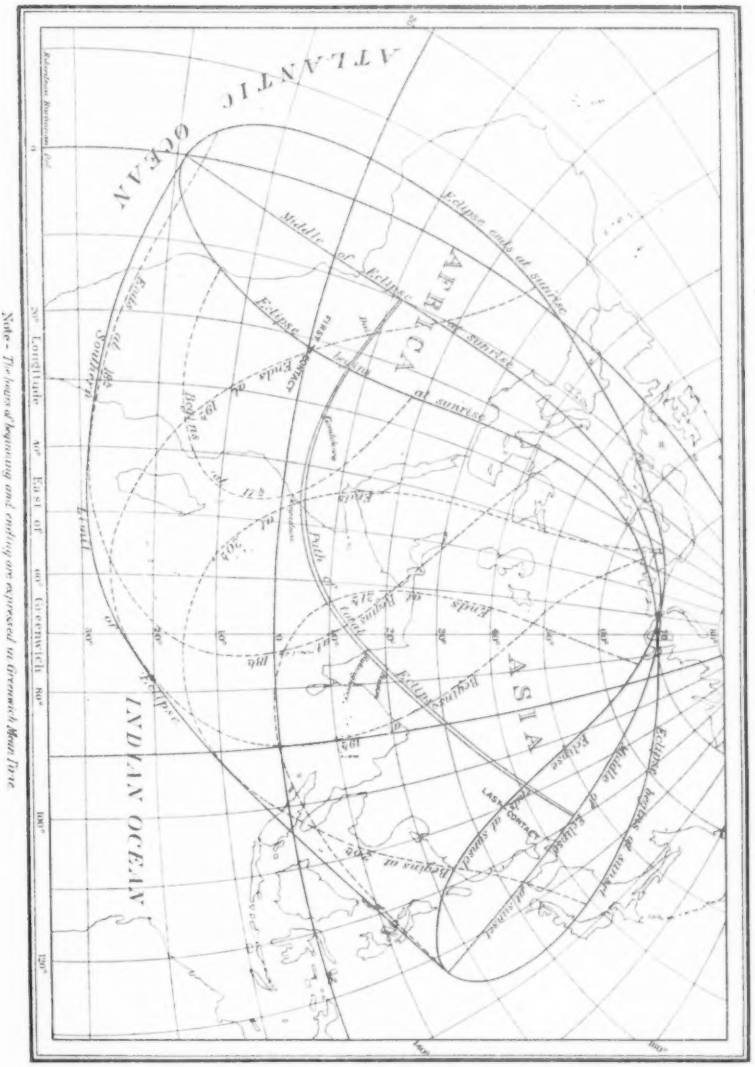
In 1898 there will be six eclipses, three of the Sun and two of the Moon.

1.—*A Partial Eclipse of the Moon, Jan. 7* will be visible generally in the eastern parts of North America, in South America, Europe, Asia, and Africa.

The southern portion of the Moon will dip into the shadow of the Earth as it passes, about one-seventh of its disk being covered at the maximum of the eclipse. The elements of this eclipse as given in the *American Ephemeris* for 1898 are as follows:

Greenwich Mean Time of conjunction in right ascension January 7, $12^h\ 9^m\ 48^s.7$

Sun's right ascension	19^h	17^m	$7^s.24$	Hourly motion		$10^s.91$	
Moon's right ascension	7	17	7 .24	Hourly motion		128 .37	
Sun's declination	22°	16′	11″.5	S.	Hourly motion	0′	20″.1 N.
Moon's declination	23	6	51 .0	N.	Hourly motion	6	41 .4 S.
Sun's equa. hor. parallax			8 .9		Sun's true semidiam.	16′	16″.0
Moon's equa. hor. parallax		54	33 .0		Moon's " "	14	51 .1


ATLANTIC OCEAN
EUROPA
ASIA
INDIAN OCEAN
Eclipse ends at sunrise
Middle of Eclipse at sunrise
Eclipse ends at sunset
Middle of Eclipse at sunset
Path of Shadow
Ends
Limits
Equator
Tropic of Cancer
Greenwich
LAST CONTACT
Middle of Eclipse
Eclipse begins at sunset
Eclipse begins at sunrise
Eclipse begins
Eclipse ends
Middle of Eclipse
Eclipse ends at sunset
Eclipse begins at sunrise
Eclipse begins at sunset
Eclipse ends at sunrise
Middle of Eclipse at sunrise
Middle of Eclipse at sunset

TIMES OF THE PHASES.

		h m Greenwich M. T.	h m Central Standard Time.
Moon enters penumbra	January 7	9 58.7	3 58.7 P. M.
Moon enters shadow		11 47.5	5 47.5 "
Middle of eclipse		12 35.0	6 35.0 "
Moon leaves shadow		13 23.0	7 23.0 "
Moon leaves penumbra		15 11.2	9 11 2 "

Magnitude of the eclipse = 0.157 (Moon's diameter = 1.0).

The first contact with the shadow will occur at a point on the Moon's disk 169° east from the north point or only 11° east from the south point, the last contact 142° west from the north point.

2. *A Total Eclipse of the Sun Jan. 21* will not be visible in America, but will be visible as a partial eclipse in the greater part of Africa and Asia and the eastern half of Europe. The line of totality begins in the heart of Africa, passes eastward across Africa, then northeastward across the Arabian Sea, Hindostan and China, ending north of the Yellow Sea, as shown upon the accompanying chart. The most favorable stations for observation will be in India, where the duration of totality, along the central line of the shadow's path, will be a few seconds more than two minutes. The maximum duration will be $2^m\ 19^s.4$, when the shadow is crossing the water between Africa and Hindostan.

The elements of this eclipse given by the *American Ephemeris* are as follows:

Greenwich mean time of conjunction in right ascension, January 21, $19^h\ 37^m\ 26^s.5$.

Sun's right ascension	20^h	18^m	$32^s.82$	Hourly motion	$10^s.52$
Moon's right ascension	20	18	32 82	Hourly motion	147.72
Sun's declination	19°	38′	40″.1 S.	Hourly motion	0′ 34″.5 N.
Moon's declination	19	6	27.1 S	Hourly motion	11 34.0 N.
Sun's equa. hor. parallax			8.9	Sun's true semidiam.	16 15 0
Moon's equa. hor. parallax		60	11.6	Moon's true semidiam.	16 23.3

3.—*A Partial Eclipse of the Moon, July* 3 will be visible throughout Europe, Asia and Africa, but will not be visible in America. The times of the phases are as follows:

	h m	
Moon enters penumbra July 3	6 46.0	
Moon enters shadow	7 45.5	Greenwich
Middle of the eclipse	9 17.4	Mean
Moon leaves shadow	10 49.2	Time.
Moon leaves penumbra	11 48.4	

At the middle of the eclipse 0.934 of the Moon's diameter will be covered by the Earth's shadow.

4.—*An Annular Eclipse of the Sun July* 18 will be visible as a partial eclipse in the South Pacific Ocean and the southern part of South America. The path of annular eclipse lies wholly upon the water. Little interest therefore attaches to this event. The eclipse begins at $5^h\ 2^m$ and ends at $10^h\ 11^m$ July 18 Greenwich Mean Time.

5.—*A Partial Eclipse of the Sun, Dec.* 13, will be visible only upon the waters of the southern ocean. The eclipse is hardly worth mentioning since the umbra of the Moon's shadow will not touch the earth at all and at the maximum only one fourty-fourth of the Sun's diameter will be hidden by the Moon.

6. *A Total Eclipse of the Moon, Dec.* 27 will be visible generally in North and South America, Europe, Asia and Africa. In America the Moon will rise eclipsed.

ELEMENTS OF THE ECLIPSE.

Greenwich Mean Time of conjunction in right ascension, December 27 $11^h\ 37^m\ 52^s.0$.

Sun's right ascension	$18^h\ 27^m\ 29^s.45$	Hourly motion	$11^s.08$		
Moon's right ascension	$6\ 27\ 29\ .45$	Hourly motion	$128\ .63$		
Sun's declination	$23°\ 18'\ 7''.5$ S.	Hourly motion	$0'\ 7''.3$N.		
Moon's declination	$23\ 30\ 53\ .2$ N.	Hourly motion	$4\ 9\ .4$ S.		
Sun's equa. hor. parallax	8.9	Sun's true semi-diam.	16 16.1		
Moon's equa. hor. parallax	54 6.4	Moon's " "	14 43.9		

TIMES OF THE PHASES.

	Gr. M. T.	Central Time.
Moon enters penumbra Dec. 27	8 32.9	2 32.9 P. M.
Moon enters shadow	9 47.5	3 47.5 "
Total eclipse begins	10 57.5	4 57.5 "
Middle of eclipse	11 42.1	5 42.1 "
Total eclipse ends	12 26.7	6 26.7 "
Moon leaves shadow	13 36.4	7 36.4 "
Moon leaves penumbra	14 50.7	8 50.7 "

Magnitude of the eclipse = 1.384 (Moon's diameter = 1.0)

OCCULTATIONS.

The usual list of occultations of the stars by the Moon will occur each month. The *American Ephemeris* gives the times of immersion and emersion for 102 stars as seen from Washington. These will be published in POPULAR ASTRONOMY each month as they are needed. On January 30 the Moon passes through the Pleiades group, occulting all but one of the bright stars.

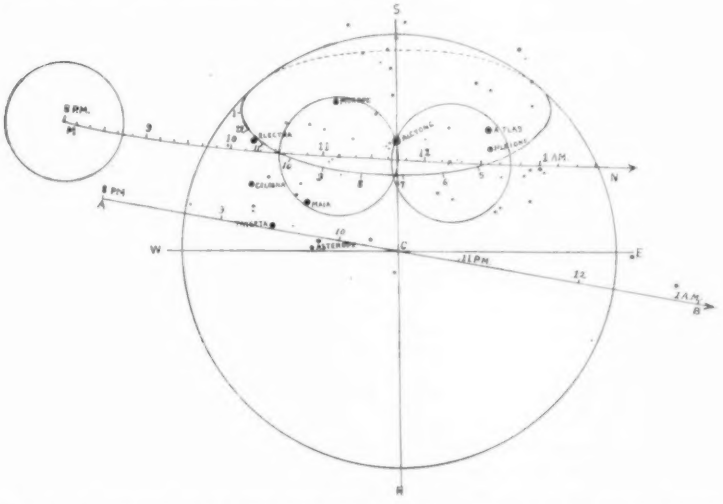


FIG. 1. OCCULTATION OF THE PLEIADES JAN. 30, 1898, AS SEEN FROM NORTHFIELD.

These occultations will be visible all through the United States and will furnish a splendid opportunity for classes in astronomy to witness a phenomenon which, while not at all rare; is interesting and instructive.

OCCULTATIONS VISIBLE AT WASHINGTON IN JANUARY.

Date 1898.	Star's Name.	Magnitude.	IMMERSION. Washington M. T. h m	IMMERSION. Angle from N pt. °	EMERSION. Washington M. T. h m	EMERSION. Angle from N pt. °	Duration. h m
Jan. 5	125 Tauri	6.0	5 42	79	6 53	265	1 11
25	16 Piscium	5.8	7 35	70	8 36	234	1 1
30	Electra	4.3	10 52	101	12 1	253	1 9
30	Celœna	6.2	10 54	59	11 57	295	1 3
30	Maia	5.0	11 35	41	12 21	315	0 46
30	Merope	4.7	12 2	160	12 22	195	0 20
30	Alcyone	3.1	12 17	108	13 16	148	0 59
30	Pleione	6.2	13 6	103	14 2	254	0 56
30	Atlas	4.0	13 9	124	13 56	233	0 47

In the chart Fig. 1 the line *A B* represents the path of the Moon unaffected by parallax, while the line *MN* represents the Moon's path as seen from Northfield. The times indicated are Central Standard time. The chart was constructed by the method explained in POPULAR ASTRONOMY Vol. II, p186, Dec. 1894. The reader can obtain the approximate times of immersion and emersion for each Star by means of a pair of dividers. Open the dividers to measure the radius of the smaller circle *M* representing the disk of the Moon. Set one foot of the dividers upon the Star and with the other strike arcs cutting the line *M N*. The intersection at the left will mark the time of immersion and that at the right the time of emersion.

THE PLANETS.

The two charts Fig. 2 show the apparent paths of the two planets Mercury and Venus among the stars during the year 1898. The path of the Sun, the Ecliptic, is also shown and the little crosses on this line indicate the place of the Sun on the first day of each month. We have not marked the dates for the Sun upon the charts, in order to avoid confusion, but if the reader will note that the Sun is in Sagittarius on Jan. 1, in Capricornus Feb. 1, in Aquarius Mar. 1, in Pisces April 1, etc., he will have no difficulty in locating the place of the Sun relative to the planets.

Mercury begins the year in Sagittarius, east of the Sun and moves westward while the Sun moves eastward, so that the two come into conjunction on Jan. 6. At this conjunction Mercury will be between the Earth and Sun, inferior conjunction. During the next ten days Mercury continues to move westward among the Stars, but more and more slowly, until on the 17th he becomes stationary in right ascension, then turns eastward, carried along by the apparent eastward movement of the Sun and interior planets, which apparent motion the reader, of course, understands to be the result of the real movement of the earth in its annual course around the Sun. For 11 days more Mercury's eastward motion is less than that of the Sun so that with reference to the latter the former is still moving westward until Jan. 28, when he reaches greatest western elongation, 25°. He then begins to gain on the Sun, overtaking that body in the constellation Pisces on March 16 and reaches greatest elongation on the east side of the Sun April 10, in Aries. The apparent motion of the planet then slows up and during May a retrograde bend in the path is traced in the constellation Aries. The Sun has meanwhile passed the planet and during this retrograde movement Mercury is again a morning planet. From June to August Mercury's path is a comparatively smooth curve, the motion accelerating until the planet overtakes the Sun, June 29, and reaches greatest elongation east August 8. During August and September the closed loop in Leo is described, the planet falling behind the Sun after inferior conjunction on Sept. 5. From October to December the path is again smooth but in the last month of the year the planet begins another back-

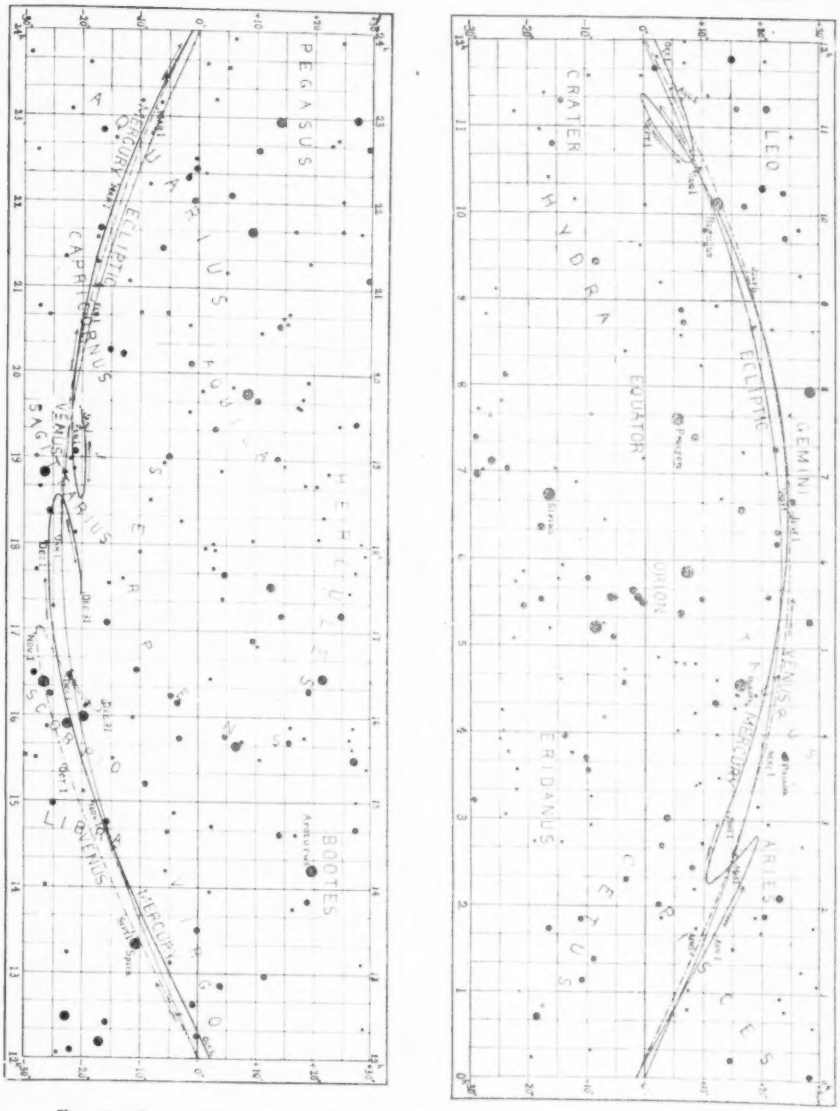


FIG. 2. CHARTS SHOWING THE APPARENT MOVEMENTS OF THE PLANETS MERCURY AND VENUS AMONG THE STARS IN 1898.

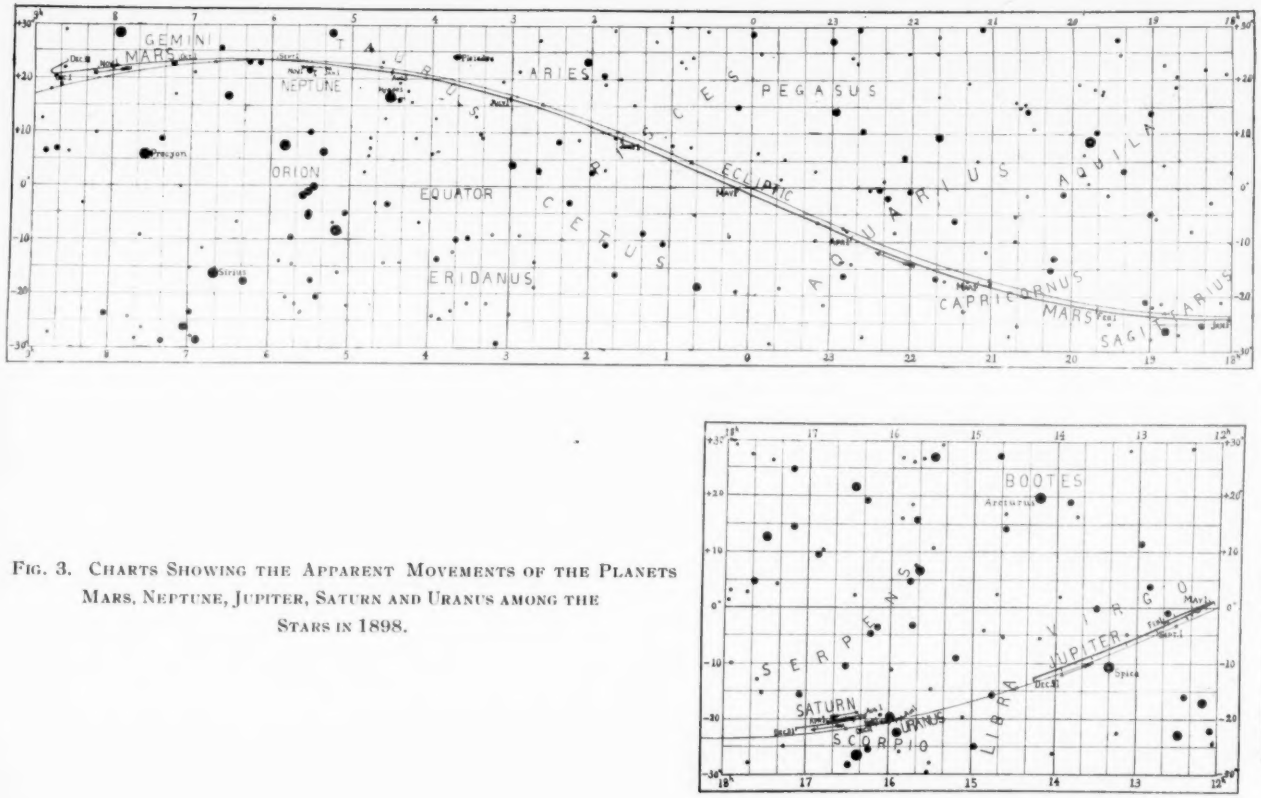


FIG. 3. CHARTS SHOWING THE APPARENT MOVEMENTS OF THE PLANETS MARS, NEPTUNE, JUPITER, SATURN AND URANUS AMONG THE STARS IN 1898.

ward movement, which, when completed in the first month of 1899, will form a closed loop like that traced in September, only reversed.

The path of *Venus* will be a smooth curve, following the ecliptic quite closely until November, when a great bend will be traced in Scorpio. When completed in 1899, this bend will be like the bend in Mercury's path in constellation Aries. Venus will pass behind the Sun on Feb. 15, and will during all the summer be evening planet and in favorable position for observation. On Dec 1 she will pass between the earth and Sun and after that be visible in the morning.

The longer chart Fig. 3 shows the apparent path of *Mars* during the year. This is a smooth curve following close to the ecliptic until December, when Mars also begins a backward turn to be completed in 1899. Mars will be in best position for observation during the later months of the year.

The path of *Neptune* is shown upon the same chart with Mars. The reader will need to use a magnifying glass in order to see the form of this curve. It begins a little west of the star ζ Tauri, extends westward for two months, then eastward for seven months, then westward for three months, passing the star ζ Tauri twice on the way. Neptune will be in the most favorable position for observation during the winter months. During the summer this planet will be on the farther side of the Sun, conjunction occurring June 12.

The apparent paths of Jupiter, Saturn and Uranus will be found upon the smaller chart, Fig. 3. Jupiter's course is through the constellation Virgo, advancing until Jan. 20, then retrograding until May 28, and advancing during the remainder of the year.

Saturn pursues a similar course in Scorpio, moving eastward until March 21, westward until August 10, then eastward again.

Uranus may be easily found this year, for its path is near the second magnitude star β Scorpii, which it passes three times during the year in its movement, first eastward, then westward, then eastward again. The planet's path lies about one degree south of the Star.

These last three planets will be in best position for observation in the spring and summer, when the Sun is in the opposite part of the heavens.

COMETS.

What new comets will appear during 1898 is, of course, beyond prediction, but there are a considerable number of periodic comets whose return is due, although not all under such conditions as lead us to expect that they will be seen.

Winnecke's comet is due at perihelion about March 20 but will be more favorably situated for observation during January and February. An ephemeris for January was given in our last number.

Encke's comet, which appears every 3 3 years, will be nearest the Sun in May but will be best seen from the Earth in July and August. No ephemeris is yet at hand.

The comet 1892 V, discovered photographically by Barnard in 1892, was found to have a period of about 6.3 years. It is due at perihelion in April, but will then be on the farther side of the Sun and so is not likely to be found.

Denning's comet, 1881 V, is due in May, but will also be behind the Sun at that time, so there is little hope of it being found. At the return in 1890 the conditions were unfavorable and it was not found. The period of this comet is about 8.3 years.

Comet 1889 VI, a very faint comet discovered by Swift Nov. 16, 1889, was found to have an elliptic path. The orbit determined was very uncertain, but if

the period 8.53 years is correct the comet is due at perihelion in June this year. It will then be on the farther side of the Sun and so not likely to be seen.

Wolf's comet, a rather bright telescopic comet, discovered in 1884 and observed at its return in 1891, is again due at perihelion this year in June. It will not be most favorably situated but will probably be visible in May and June.

THE CONSTELLATIONS AT 9 P. M., JANUARY 1, 1897.

Brooks' comet, 1886 IV, is due in August. Its position is not as favorable as in 1886, but it will probably be visible from May or June to October. It was a faint nebulous object in 1886. In 1892 it was hidden by the rays of the Sun at the time of perihelion.

Comet Tempel I, discovered by Tempel in 1867 and since observed at several apparitions, at intervals of 6.5 years will be nearest the Sun this year in October.

Its position is very unfavorable but it may possibly be found when near opposition in February and March.

A faint comet discovered by Tuttle in 1858 was found to be periodic. It has never been rediscovered, but if the period 6.61 years is correct and has remained unchanged, the comet is due at perihelion about January 1, but in unfavorable position.

VARIABLE STARS.

I. A. PARKHURST.

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

1898.

U CEPHEI.

	d	h
Feb.	3	10
	5	22
	8	9
	10	21
	13	9
	15	21
	18	9
	20	21
	23	8
	25	20
	28	8

ALGOL.

Feb.	9	10
	12	7
	27	15

λ TAURI.

	d	h
Feb.	3	7
	7	6

R CANIS MAJORIS.

Feb.	5	15
	14	18
	23	19

Every 8th min.
$P = 1^d\ 3^h\ 16^m$

S CANCRI.

Feb.	5	11
	14	23
	24	11

S VELORUM.

	d	h
Feb.	5	23
	11	21
	17	19
	23	18

δ LIBRAE.

Feb.	1	15
	3	23
	8	14
	10	22
	15	14
	17	22
	22	13
	24	21

U CORONÆ.

Feb.	6	21
	13	19
	20	16
	27	14

U OPHIUCHI.

	d	h
Feb.	5	12
	13	21
	22	7

Every 10th min.
$P = 20^h\ 8^m$

RS SAGITTARII.

Feb.	3	23
	8	19
	25	17

W DELPHINI.

Feb.	12	14

GENERAL NOTES.

The next number of this publication will end volume five. All subscriptions running even with the volume will close with that number. Notices of expiration will be promptly sent as reminders.

Twelve numbers of this magazine will be published during the year 1898, which brings it to the end of volume six. The subscription price per volume and per year for 1898 will be found on the first page of the cover of this number.

Observations of the Milky Way.—The second article in the series setting forth the study of the Milky Way, by A. Pannekoek is given in this number. The suggested work is very important, and it is hoped that many amateurs who have some experience in observing will be inclined to undertake it. The charts referred to in the papers will soon be received. They will be furnished to all observers free of charge. From a private letter just received we believe that Mr. Pannekoek will gladly aid further in this useful work in any way that may be helpful to observers.

Dr. J. Morrison's Articles which have been published from month to month have awakened considerable interest at home and abroad. This is so probably because of the lucid and definite way in which he writes on subjects somewhat difficult for the amateur or the student of astronomy to grasp as they are usually treated. Every student of astronomy wishing to master the work of the American Ephemeris and Natural Almanac should have the entire series of articles published by Dr. Morrison in late volumes of this magazine.

Dr. See in the East.—The number of new double stars discovered at the Lowell Observatory has been so considerable that Dr. See has decided to issue without further delay his first catalogue. He left Flagstaff Nov. 18, and has since been in Boston and at other points in the East. He is now at the Naval Observatory in Washington discussing his accumulated work, and will soon forward his observations to the printer. It is said that the new catalogue will be a work worthy of his distinguished reputation as an authority on double stars. We notice by the papers that he has been lecturing at some points in the East, and it is announced from Philadelphia that he will present an important paper to the American Philosophical Society on Jan. 7.

The Total Solar Eclipse of Jan. 22, 1898.—In our September issue page 255 will be found a brief, though carefully prepared article giving map and data concerning the total solar eclipse which will occur on the 22d of this month. Also, in the November number page 378, will be found an article copied from *Nature* which gives information in detail concerning stations for observation in the path of totality.

In the last issue of *Knowledge*, December, 1897, is an article of interest on the same theme. The writer mentions the mistake made by English astronomers, in the solar eclipse of Aug. 9, 1896, in not occupying every available station. Those that were occupied in Japan were according to meteorological prophecy much the surer, but those not occupied generally for the same reason, proved to be in this particular instance the stations from which results could have been obtained.

So much has been published about the different available stations for the coming eclipse that it is more than probable that all, or nearly all, will be occupied by earnest observers who will seek for the most possible that the precious minutes will yield to them, and by them to science generally.

The principal things to observe were given in the first article referred to, and are:

1. Photographs of the spectrum of the reversing layer.
2. Spectrum photographs to determine the velocity of the rotation of the corona.
3. Repetition of the photographs of the spectrum of the corona with a different instrument.
4. Photographs of the spectrum of the corona.
5. Photographs of the corona on a large scale (40-foot lens) on the plan first employed by Professor Schæberle in Chili.
6. Photographs of the corona with a portrait lens on 8x10 plates.
7. Photographic photometry of the corona, as in the Lick Observatory of January and December 1889, April 1893.

Lantern Slides in Teaching Astronomy.—At present we are instructing a class in astronomy in Carleton College consisting of twenty-seven members

of the Junior and Senior classes of the various courses of the regular curriculum of the college. In all courses but one, the scientific, the study is optional with the student. It has, however, been our purpose to make the study as attractive as possible, by every means of illustration within our reach that the large benefits of it might be definitely and usefully fixed in the mind of the student in his first real work in it. First impressions mean so much in any line of study pursued by young minds, that it has seemed to me wise and even necessary to best results to do this.

The means of illustration now being tried is that of good lantern slides under an oxy-hydrogen light. Although an evening hour, usually from seven to eight o'clock, is employed, the exercise is not made a regular lecture. The exhibit is made in the regular class-room which will comfortably seat forty or more students, and members of the class are allowed the privilege of inviting a few friends, which they always do. Then the instructor proceeds with the topic of study to which the lantern slides relate, as if reviewing a topic regularly. The students ask questions in regard to any feature presented by the slide under view, and so in wholly informal way, better results are secured than are usual in the ordinary way of review work. We have the advantages of fine instruments in visual and photographic lines and can make our own slides. In so doing the many incidental facts and circumstances attendant upon their preparation furnish much of detail which always interests students; because such matter must be almost wholly new to them. Such things as the time of exposure of a plate, the field in the sky that it covers, over or under exposure, and the effects therefrom, the cause of rings around the bright stars, and a great variety of other things that the eyes of observing students will catch readily if the attention is what it should be.

In presenting the Moon, as one topic, in this way, our plan has been to use thirty or forty slides in an hour, and first show the lunar surface as a whole, calling special attention to large craters by name, with instruction as to size, locality and things peculiar to each; next the plateau and smooth valley regions, then the mountain ranges and isolated peaks, and finally the systems of streaks shown by Tycho, Copernicus, Kepler and a few other bright craters. In this the thought is to familiarize the students quite definitely with the main features of the lunar surface as they really appear in the telescope. It will be a great advantage before showing any slides if the student can have the use of a good 4-inch telescope to leisurely see these markings on the Moon, and locate and name them from such a map as that published by Messrs. Poole Brothers in Chicago. Then when the teacher reviews the theme, the student will be able to follow with lively interest and great profit. After this general review the instructor may usefully take up the probable cause of these formations, using such a course of reasoning as that found in Nasmyth and Carpenter and Neison, whose works ought to be in every teacher's library. With the beautiful plates from these books made into lantern slides the teacher may give more information to a class in an hour than individuals would get in reading the same books for much longer time probably.

In the same way we are following all the leading topics of Young's General Astronomy very satisfactorily.

The New Superintendent of the Coast Survey.—In our last issue of POPULAR ASTRONOMY we mentioned the appointment of Professor H. S. Pritchett as superintendent of the Coast and Geodetic Survey. The appointment is so good a one, that we think it proper to give our readers a few additional notes on the career of the new superintendent, and we take occasion to express more fully

the gratitude felt by men of science throughout the country towards Secretary Gage for making so admirable a selection. It is said that when the distinguished Secretary of the Treasury saw how the Coast Survey had for years been made the football of politicians he decided to name as superintendent the best qualified man in the country, and to base his selection wholly on scientific grounds. No more jobbery is to discredit one of the most important of the national institutions designed to advance the course of science, and good men of science in the Survey will not again be disturbed for political or personal reasons. The present selection was directed wholly by the preference of astronomers and other qualified men of science, and all are much pleased that at least one important government bureau is under competent direction and within the pale of the Civil Service rules, where the merit system prevails. It is certain that by nature and by training Professor Pritchett is devoted to purely scientific interests, and that under his able direction the work will again be placed on a basis worthy of what it was in days gone by under Bache and Peirce.

The position is one requiring a thorough training in pure mathematics as well as in astronomy and physics, and Professor Pritchett's extensive acquaintance with the best scientific work in this country and in Europe makes him preeminently fitted for this high place in the nation's service. Moreover he is possessed of the high character and breadth of mind, which are absolutely essential to, but not always found in, those charged with the administration of institutions involving the rights of many persons and the scientific interests of the nation.

That so many persons entrusted with the administration of observatories, laboratories, bureaus, and other scientific or educational institutions should deliberately countenance or passively permit a policy which allows the intriguers to be rewarded while the meritorious workers go unrecognized, or on the other hand that superintendents or directors should rob their subordinates of the fruits of their scientific labors, shows not only an amazing lack of fitness for any administrative responsibility, but a lack of personal character wholly unworthy of a man of science. There are signs that some of these things which have been but too prevalent in this country, are at last breaking away—it is time changes for the better were coming if anything of a high character is to be expected of our institutions. When these improvements do come there will be many who will thank Secretary Gage, and those who follow the illustrious and patriotic example he has set in the matter of the coast survey.

Professor Pritchett comes of one of the oldest and most distinguished families of Missouri, and like the younger Herschel inherited his scientific abilities and tastes. A son of Professor C. W. Pritchett, for many years director of the Morrison Observatory, at Glasgow, Missouri, and formerly a student of the Bonds and Benjamin Pierce, his own training was acquired originally at the Naval observatory under the guidance of Professors Hall and Eastman; it was afterwards extended and developed at the Washington University in St. Louis, where he held the chair of Astronomy, once graced by the illustrious Chauvenet. The years of 1894 and 1895 were spent at the Universities of Berlin and of Munich in special research connected with mathematical Astronomy; and at the latter University his researches on the Satellites of Saturn were rewarded by the degree of Doctor of Philosophy.

Professor Pritchett's other contributions and scientific labors have been very numerous; and alone would have fully engaged the attention of a less active but capable man. He was Assistant Astronomer at the Naval observatory from 1878 to 1880 and in 1882 took part in the observations of the Transit of Venus. Dur-

ing 1883 he took an important series of Pendulum observations in Australia, China and Japan. He organized and directed the work of the Washington University eclipse party in California (1889), which secured many important photographs since published and now well known to astronomers. A great deal of his attention has been given to latitude and longitude work in the service of the Government, and he has made a special study of the work of Geodesy. His purely astronomical work includes determinations of the mass of Mars, rotation period of Jupiter, diameters of Mars, Jupiter and Saturn, and numerous observations of double stars. Since 1889 he has been President of the Academy of Sciences in St. Louis, and under his direction a fine series of publications has been brought out by that learned body.

It will thus be seen that the new Superintendent of the Coast Survey is one of the foremost men of science of the country; few of his countrymen engaged in the noble work of scientific investigation are more worthy of the chair of Benjamin Peirce, and we predict that none will fill it with more honor to himself or greater credit to the nation.

United States Naval Observatory.—Reports of the Superintendent of the United States Naval Observatory for the fiscal years 1894 and 1897, each of which ends June 30, have been received. A statement accompanies the reports for these years, that similar reports for the years 1895 and 1896 were published in the reports of the Secretary of the Navy and that they had not been and probably would not be published separately.

Professor William Harkness, Astronomical Director, reports that Professor Stimson J. Brown has been in charge of the 26-inch equatorial. As usual, this instrument has been employed almost exclusively on faint and difficult objects which could not be reached by smaller telescopes. The work accomplished during the year ending June 30, 1897 was as follows: Brooks' periodic comet, 1889 V = 1896 VI was observed twenty-three times. Giacobini's comet was observed five times. Perrine's 1896 *I* = 1897 I was observed Nov. 6, 8 and 9. On the latter date it was visible in the 5-inch finder, and therefore the work of making further observations was transferred to the 12-inch equatorial. Perrine's periodic comet, 1896 VII was observed three times.

The observations of the four comets have all been completely reduced and published in the volumes of the *Astronomical Journal*.

During the months of May and June an attempt was made to find D'Arrest's comet, the ephemeris used having been carried forward from the last apparition, but the search proved unsuccessful, partly on account of unfavorable weather and partly because the motion of the comet kept it continually on the verge of the morning twilight.

The satellites of Mars were observed whenever possible from November 18 to December 28, 1896, and during that period 24 observations of Deimos and 6 observations of Phobos were made by the method of position angles and distances.

On March 29, 1897, observations were begun on what is intended to be a general revision of the more important double stars, such as well known binaries, suspected binaries and new or difficult doubles. Although nearly every subsequent clear night, except Sundays, has been utilized for that purpose, only 98 observations have been secured, while an equal number of attempts proved futile. Out of thirty-nine nights of actual work fifteen proved fairly good but on only three of them could so high a power as 888 be used. On the remaining twenty-four nights observations were either impossible or limited to objects which would have been easily within reach of a 12-inch telescope under favorable conditions of weather. As a part of this work, Sirius and Procyon were examined in the early twilight, but the condition of the sky was unfavorable and nothing was seen of their companions.

Last January the Moon passed very near to Mars and arrangements were

made to secure photographs of the spectra of the two bodies under nearly identical conditions. Trial spectra were obtained on both objects, but a long period of cloudy weather rendered the bodies invisible at the time of the January conjunction, and when the February conjunction arrived Mars was so far from the Earth that the scheme was impracticable.

The diameters of Mercury and Venus have been measured with the filar micrometer whenever sufficiently favorable conditions occurred. The observations of Mercury have little value on account of the unsteadiness of the images, but on three occasions the images of Venus were very fine for daylight observations, and as the resulting diameter of the planet at distance unity they gave respectively, 17″.60, 17″.65 and 17″.56.

In addition to the usual routine office work the observations of Titan and Iapetus for 1894, 1895 and 1896 have deen completely reduced, and the solution of the normal equations for the correction of the elements has been finished, but as the work has all been done by Professor Brown he thinks it should yet be checked by some one else, in order to guard against the possibility of systematic errors in the computed coördinates and in the coefficients of the observation equations. There were 150 equations of condition, equally distributed between the three years, and also between the two coördinates $\Delta\alpha$ and $\Delta\delta$. The probable error of a single observation is ± 0″.313, and the resulting mass of Saturn is, from Titan 1 : 3490.3, and from Iapetus 1 : 3489.2.

Professor Edgar Frisby's work with the 12-inch telescope has been: Thirty-three observations of asteroids, Perrine's comet, 1896 f = 1897 I six times, Perrine's comet 1896 g = 1896 VII six times, eight occultations of stars by the Moon, 5 eclipses of Jupiter's satellites, the diameter of Venus measured on seven different days and the Sun was examined for spots on 4 days. These observations were reduced, and such as need prompt publication have been printed in the *Astronomical Journal*.

The work of those in charge of other instruments will receive notice next time.

Kites over Two Miles High.—The December *Popular Science News* reports that kites were sent up in the month of October from the Blue Hill Meteorological Observatory carrying meteorological instruments to the height of 10,900 feet above the top of the hill, or 11,500 feet above sea level. The kites were started at 3 50 o'clock in the afternoon and reached the highest point of ascent at 6 o'clock. At the highest altitude the temperature was 43° while it was 73° at the ground, showing as much difference as should be expected.

New Form of Mirror for Reflecting Telescope.—In our November number page 345, we called attention to a paper read by Charles Lane Poor, of Johns Hopkins University on a new form of mirror for a reflecting telescope, saying that the form described was that of a paraboloid of revolution with the central part removed. This paper at the dedication of the Yerkes Observatory occupied the attention of the visiting astronomers and physicists at one of the conferences as prominently as any other and the point, whether or not such a mirror, if it could be made would be good or worthless was not even raised if our memory serves us rightly. Attention was chiefly directed to methods that might be employed in grinding such a mirror. In the minds of those who participated in this discussion, this seemed to be the chief difficulty. It would hardly seem possible that Mr. Poor, in his study of the qualities of such a mirror should have wholly overlooked so important a fact as that raised by Professor Schæberle in the Astronomical Journal No. 419 which severely criticises the proposed form of mirror, and declares it worthless. We give below his own language:

"How completely certain fundamental principles of optics have remained hidden ever since the invention of the telescope is perhaps best illustrated by the suggestions, made at various times, to construct a reflecting telescope in which the mirror is a portion of a paraboloid of revolution cut from the surface near the extremity of the *latus rectum*. The reflected rays then being at right-angles to the incident rays, no dome would be required for such a telescope, and there would be no secondary mirror.

This form of telescope was recommended by Professor Pickering more than sixteen years ago (see *Nature* for August 25, 1881). In the *Johns Hopkins Circular* for June, 1897, Professor C. L. Poor advocates the construction of such a telescope and, according to the reports of the dedication exercises of the Yerkes Observatory, Dr. Poor on that occasion exhibited such a mirror constructed by himself.

To show the utter uselessness of such an instrument only a few approximate computations need be made. Let L denote the distance from the focus to the center of the mirror which is evidently inclined about 45° to the line of sight. If D denotes the minimum diameter of this elliptical mirror the maximum diameter must be D sec 45° if a circular cone of rays is to be used.

The linear distances from the focus to the nearest and most distant points of the mirror will then be approximately

$$\text{Least distance} = L - \tfrac{1}{2} D$$
$$\text{Greatest distance} = L + \tfrac{1}{2} D$$

If we assume $\frac{L}{D} = \frac{7}{1}$ the greatest distance divided by the least distance becomes 1.16.

This quantity is approximately the *blurring factor* for the given ratio of focal length to aperture for this form of instrument. For a star which is, say only 5′ from the optical axis of the telescope, and in a plane containing this axis and the longer axis of the mirror, the image will, therefore, not be a point, but rather a line of light, the length of the line being no less than 48″, or more than ¾ minute of arc! Exactly at the focal point this star-image will be a point, but for all other positions of the image the definition will be worthless.

These considerations are but special applications of my results given in No. 413 of the *Astr. Journal*.

Further illustrations seem to be unnecessary."

An extended article is already in hand, on the above matter, which will appear in our next issue.

BOOK NOTICES.

The Elements of Geometry.—This recent book by Professors A. W. Phillips and Irving Fisher, of Yale University, is published by Messrs Harper Brothers, of New York, and belongs to the Phillips-Loomis series. It contains 540 pages, including plane and solid geometry to the usual amount, with an appendix to plane geometry, thirty pages of exercises adapted to each of the nine books, thirty-six devoted to modern geometry as an introduction to this useful study, a table of weights and measures in English and metric demonstrations and an index to definitions.

This book is not a revision of the geometry by Professor Elias Loomis. It does use the terse and accurate statements and definitions found in Loomis' book

and it maintains the high standard for vigorous demonstration which gave the former text justly an enviable reputation. The arrangement of this book in some ways is essentially new. The introduction presents in brief compass the outlines of the branch to be studied, coming at once to actual study itself. The definitions are scattered through the book as needed, and they are of easy reference by means of an index. Especial emphasis is laid on the constructions in plane geometry which the student is expected to master thoroughly. In the geometry of space the figures consist of half-tone engravings from photographs of actual models recently constructed for use in the class-rooms of Yale University. In regard to these figures, this book is much superior to any other work in English with which we are acquainted. We do not see how they could be improved. Every teacher of experience knows that students have real difficulty —even the best—in comprehending some figures of space geometry. Under such circumstances it is impossible for the student to advance a single step in his study until this needless hindrance is out of the way. These figures are a great improvement in this particular. In all high schools, where the models can be adopted, it would be a gain on present methods used, where the figure constructed by the student is alone depended on. Not that the student should have less exercise in preparing good figures, but rather that he should work with clearer ideas or concepts of that which is to be presented. This book seems to us to be an admirable one, and it is commended to teachers.

Klein's Famous Problems in Elementary Geometry.—We have received a little book of 80 pages by Professors W. W. Beman, of the University of Michigan and D. E. Smith of the Michigan State Normal College, titled Klein's Famous Problems in Elementary Geometry. The text is an authorized translation of P. Klein's vorträge über ausgewählte fragen der elementar geometrie ausgearbreitet von F. Tägert, and treats of the three famous problems, the duplication of the cube, the trisection of an angle, and the quadrature of the circle.

The subject-matter of this little book was urged upon to the attention of the German association for the advancement of the teaching of mathematics and of the natural sciences at a recent meeting held at Göttingen by Professor Felix Klein for the avowed purpose of bringing the study of mathematics in the university of that place into closer touch with the work of the gymnasium. "That Professor Klein is likely to succeed in this effort is shown by the favorable reception accorded his lectures by the association and the uniform commendation of the educational journals and the fact that translations into the French and Italian have already appeared." One reason for this success lies in the fact that the treatment of these problems is in an elementary manner, not even the differential nor the integral calculus being required.

The method of their study being, in the main, to answer such questions as: Under what circumstances is a geometric construction possible? By what means can it be effected? How can we prove that ϵ and π are transcendental? The French translation referred to above was by Professor J. Griess, of Algiers.

In speaking of the object of presenting these problems in his own way, Professor Klein said: "The more precise definitions and more rigorous methods of demonstration developed by modern mathematics are looked upon by the mass of gymnasium professors as abstruse and excessively abstract and, accordingly as of importance only to a small circle of specialists." To counteract this view and its tendencies, he undertook, last summer the course of lectures already briefly referred to, which had for its object to show the possibilities of elementary geometric constructions as developed and used in modern science. It is reported that these lectures elicited great interest and the attendance on them was flatteringly large.

In our judgment there is no question at all in regard to the wisdom of Professor Klein's plan of work and its large possibilities when in competent hands. It is the thing which needs to be done in America. Its modern scholars in the mathematics might do wonders in the same direction if such work were wisely undertaken.